REPORTS

OF THE LATE

JOHN SMEATON, F.R.S.

MADE ON

VARIOUS OCCASIONS,

IN THE COURSE OF HIS EMPLOYMENT

AS

A CIVIL ENGINEER.

IN THREE VOLUMES.

VOL. III.

LONDON:

PRINTED FOR LONGMAN, HURST, REES, ORME, AND BROWN,
PATERNOSTER-ROW.

1812.

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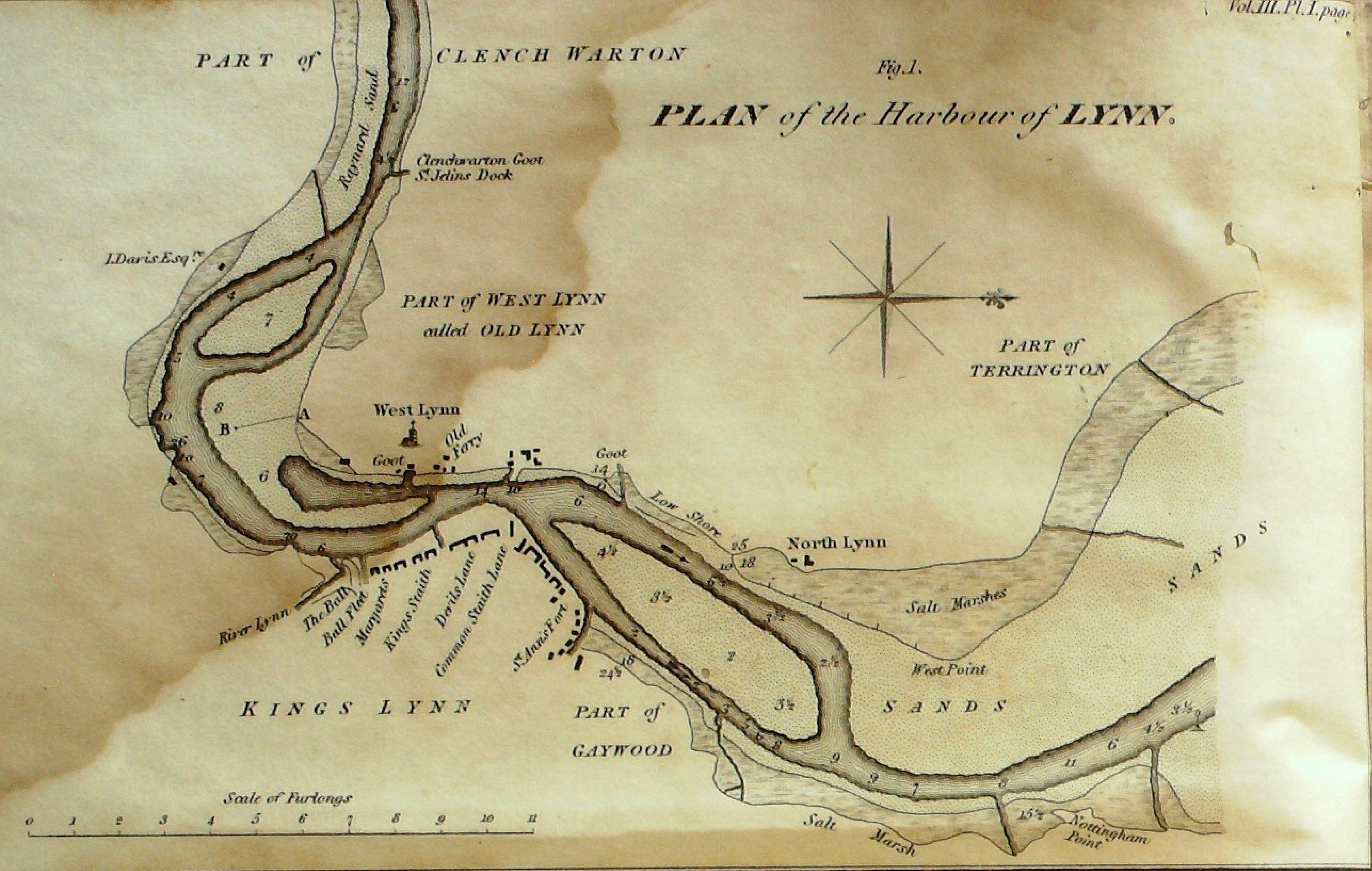

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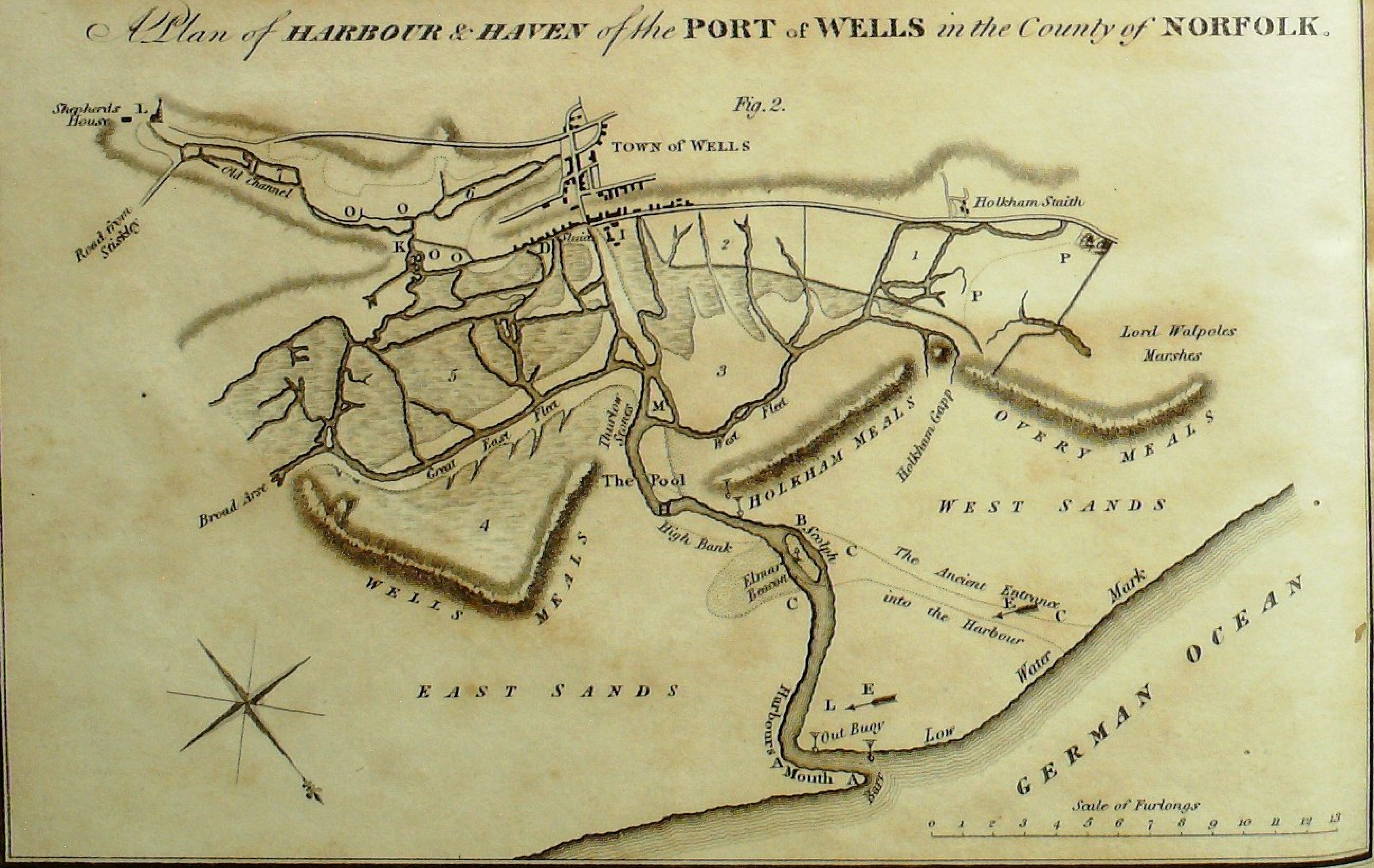

J. Farey Junr. delin.

Engraved by W. Lowry

REPORTS, &c.

KING'S LYNN HARBOUR.

The REPORT of JOHN SMEATON, Engineer, relative to the Harbour of *Lynn* in *Norfolk*.

THE Matters to be reported upon as given me in charge by the Magistrates of *Lynn*, were principally the following:

First, The preservation of vessels lying in the harbour of *Lynn*, from the annoyance of winds and waves; not only from the sea, but from the broad river above the town, when the wind happens to be in that quarter, and also from the raging tides that often accompany them, and drive the Vessels from their moorings:

Secondly, The preservation of the banks of the river, and more especially those near the town, from the action of the winds and seas, accompanied also with too rapid a tide.

The better to enable me to acquit myself upon these subjects, I carefully examined the channel of the river *Ouse*, from the roads near the *Ferror Beacon* to *German's Bridge*; and also the banks thereupon, and more particularly those within two miles of the town

Note.—In the plan of the harbour, Fig. 1. Plate 1. the figures in the channel shew the depths in feet and half feet at low water; the other figures shew the height of the ponds, lower shores, salt marshes, and banks above low water mark.

of *Lynn*. I have also carefully viewed and examined the circumstances attending the said river, from *German's Bridge* to *Denver Sluice*; so far as they appeared to me to have any relation to the business before-mentioned.

In the course of these enquiries, I had the pleasure to find, that the channel of the river, and particularly that part to seaward, not only from the accounts of the pilots who attended me, but from my own remarks, compared with former accounts and reports, was, at the time of those observations, *viz.* in the month of *July* 1766, in as good condition as it had been known for many years; and in fact without any material cause of complaint. That a bar had formed itself in the upper mouth of the west channel, and that the current at low water was wholly confined to the east channel, which had in consequence proportionally improved.

This is indeed a very material change in the state of the channel and harbour for the better; the contrary condition having been complained of for years past, *viz.* the choaking of the harbour and channel to seaward with sands, and the great tendency of the current to take the west channel instead of the east; which latter (as it seems) was that, which, according to the unanimous opinion of all those who have reported upon it, was the desirable channel to be maintained, and if possible improved; the doing of which has been the subject of much projection and altercation: but as nothing appears to have been done in consequence, but that Nature has very kindly brought matters into a more desirable state, it seems of the utmost importance to propose nothing for execution, that shall counteract her intentions; nor while we are relieving one evil induce a greater.

According to all accounts, the point below the crutch on the east side of the river, called at present *Nottingham Point*, projected much further to the westward: and another point of land on the west side of the river, below *North Lynn*, but above the said *Nottingham Point* according to the course of the river, projected further eastward; so that, to a person standing upon the quay called the *Common Staith*, at *Lynn*, the sea was land locked by these two points; but that now, by the gradual wear of one or both of them, an observer standing at the same place, will, at high water, see the sea considerably open between the said points; and the wind being in that or nearly that direction, that is, betwixt N. N. W. and N. N. E. and a strong spring tide of flood, the ships are apt to ride very unquietly that lie within the point formed by the *Common Staith* and the *Ball*, which may now be reckoned the port of *Lynn*, and where the ships chiefly lie to be loaded and unloaded from the merchants' yards.

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This evil I find has been complained of for many years; and in the year 1741, a scheme was offered by Mr. *John Rosewell*; which was to build jetties from these two points so as to produce the same land lock as formerly: and this he imagined would not only redress this immediate grievance, of too much swell running into the harbour, but also others at that time also greatly complained of; that is, obstruction by sand, too shallow a channel, a high bar in the east channel, and too great a diversion of the current into the west channel.

That those jetties might be of some use in checking the swell of the sea, cannot be denied; but the ill effects they were likely to have by encreasing the tendency of the out channel to the westward, is set forth with great justness and spirit, in a small pamphlet, published in the year 1742, entitled, *Some thoughts on Mr.* Rosewell*'s and other Schemes, now proposed for amending* Lynn *Channel and Harbour**; which, as I suppose it in every ones hands, to save repetition, I recommend to a re-perusal, from the beginning to and including the 9th page. And indeed Mr. *Rosewell*'s reasoning, if such it can be called, concerning the improvement of the east channel by means of those jetties, has not been more solidly refuted by the author above referred to, than it has since been by Nature herself: for it seems very manifest, that in proportion as the points, particularly *Nottingham Point*, have been worn away, the channel has tended more eastward; and has improved in proportion as the west channel has decayed, which must be expected from an union of the two forces. As therefore the maintenance of the channel out to sea, in the good condition in which I found it, I look upon as a *primary* consideration; I entirely agree with the author before-mentioned, that it would be a dangerous expedient to reinstate the two points above-mentioned, by the building of jetties: on the contrary, I am of opinion, that where a channel must be maintained through a vast mass of sand, capable of shifting by winds, seas, currents, and every temporary impression of power thereon, that the more directly the waters make their passage out to sea the better.

Nor am I very clear, that the reinstating of the points would entirely cure the evil at present complained of; they being at too great a distance from the interior harbour, and must necessarily be placed at so considerable a distance from each other, that unless the entry was entirely spoilt, I apprehend the seas would still find the way within the heads: and in so long a fetch to the place where the ships lie, would gather and still disturb them at their moorings.

Nor can they be of much use in checking the too great indraught of the tides, at present complained of; for the passage between them must be very narrow to produce a sensible

* This pamphlet is anonymous, but I since understand was wrote by Mr. *Elstobb*. See Appendix to this Report.

ſenſible effect, and in proportion as it was contracted, it would wear deeper, and thereby ſtill admit nearly the ſame quantity of water to paſs. Yet, if they could be ſo made as to check the raging tides, they would check the moderate ones too; and I believe all agree in opinion, that in the ſituation of *Lynn* harbour, the greater the efflux, which in great meaſure depends upon the influx, the better channel may be expected to be maintained: too great tides may be a partial and temporary evil, but it appears to me in the preſent caſe a fault on the right ſide; and it ſeems that in this, as well as many affairs of human life, the judgment conſiſts in chuſing *the leaſt of two evils.*

I cannot however agree in recommending the expedient mentioned in the latter part of the pamphlet above quoted; that is, damming up the old river at the weſt point, and cutting a new one through the land, down to the road; for this, if not made equal with the mean capacity of the old river, would check the influx of the tides; and if ſo made, would be a moſt monſtrous expenſe, and at laſt the event would be uncertain; for by producing an alteration in the ſet of the currents, without the mouth thereof, it perhaps is out of the power of human foreſight to ſay with certainty, that (after ſo great an expenſe) ſome bar or impediment might not be thrown up, producing an equal obſtruction to thoſe then complained of; but thanks to Nature for relieving us from the neceſſity of ſo chargeable an expedient, and giving us the opportunity of *knowing when we are well.*

The ſimple point of view, that in my opinion is neceſſary to be attended to for the preſervation of the channel, is to do nothing *materially* to affect the indraught of the tides, or to diminiſh the quantity of freſh waters coming down the river from above: as to the reſt, it muſt be left to Nature, and though in ſuch a multitude of acting forces and diſturbing cauſes, the goodneſs of the channel muſt by turns become *better and worſe*; yet the grand principles of preſervation being maintained in all the vigour poſſible, after a wrong turn happens a right one will ſucceed, as experience has ſhewn to be the caſe; at leaſt leave Nature to herſelf while tending right, it is time enough to help her when we are ſure ſhe is going wrong.

It is obſervable, that the point formed by the *Common Staith*, and running out betwixt that and *Common Staith Lane*, may be conſidered as the jetty, whereby the ſhips lying above in the interior harbour, are ultimately defended from the ſwell coming in from the ſea; and it is only the ſwell that gets round this point from the ſea that affects the ſhipping; for in fact, the ſhips that lie in the channel of the river, between the *Purfleet* and the *Ball*, are land locked by this point. This jetty has very much the appearance of having been artificially carried out as well as defended by ſtone wharfing for this very purpoſe.

purpoſe. The river is however ſtill a furlong, that is, 220 yards, wide at this point, according to the plan; the channel lies over to the oppoſite ſhore, where it is ten or twelve feet deep at low water, whereas it gradually ſhallows towards the *Lynn* ſide, leaving the ground dry at low water for above a chain in breadth.

If I were obliged to recommend ſomething in the *jetty way*, it would be to run out this wharf about a chain further, that is, twenty-two yards, being one-tenth of the whole width of the river. I am very clear that ſuch a projection, immediately before the ſhipping, would afford more protection than ſix times as much work done at the two points below; which are at the mean diſtance of a mile and half; and this without being attended with any ill effect upon the channel below. The only objection that I ſee to this ſcheme is, that by narrowing the channel in this the narroweſt place, it would in ſome meaſure check the influx of the tides; and throw the water more powerfully upon the oppoſite ſhore, juſt below the ferry, the defences of which are already too weak: but if this bank were effectually defended by a ſufficient body of rubble ſtone, applied in ſuch a way as I ſhall mention, when I come to ſpeak upon the defence of the banks, the effect would be to ſcour out a channel ſo much deeper in this place, as, by creating an equal ſection, would furniſh the ſame quantity of tide water as at preſent, and probably might deepen the channel on the *Lynn* ſide; at leaſt ſomething might be done to intice it to act in that manner.

It is obſervable, that at the end of *Common Staith Lane* there is a conſiderable prominence of rubbiſh that has gradually been formed, and that ſomething of the ſame kind has been thrown out partly from the lanes, and partly from the houſes, quite away to the *Purfleet*, and higher: I look upon it, that it is owing to this body of rubbiſh, that the channel of the river edges over ſo ſoon to the weſt ſide; if this body of rubbiſh were dug away as near to the buildings as can be done with ſafety, and taken down to or below low-water mark as far as the *Common Staith*; that the ebb tides, accompanied with the land floods, would improve the channel, and enable the ſhips to lie not only lower down, but cloſer in, and thereby more effectually ſhelter them from the ſeas, which would be broken off by the *Common Staith* point; and this is a ſtep that I would recommend, whatever becomes of the propoſition of an extenſion of that point.

I come now to the defence of the ſhipping when the wind is at S. W. or weſterly; that is, when it blows right down the broad river which extends above the town; and with this view it obviouſly occurs, that if a jetty or break-water were carried out upon the ſands from the point above *Old Lynn*, this would in ſome degree ſhelter the ſhipping that lie from the *Ball* downwards: but yet, unleſs the jetty be extended from A to B in the plan, that

that is, the length of a furlong, or 220 yards, the veſſels lying at or near the *Ball* will ſtill be expoſed almoſt as much as before: on the other hand, this work will throw the current more forcibly into the bite or great hollow oppoſite this point, where the water ſets already too hard, and is making daily depredations. I would therefore beg leave to ſuggeſt, that as no ſhip lying from the *Ball* downward, can be ſubject to a direct fetch of more than a mile in length; and ſince in this length no great ſwell can be raiſed, but only a ſhort chopping ſea or windwaſh, which would ſignify little, independent of the force of the wind and a ſtrong tide of ebb, both which muſt remain; I ſay, I would put a query, whether it would not be adviſeable at once to endeavour to encreaſe the ſecurity of the veſſels in the harbour, by improving their moorings; which I apprehend might be done by putting down a row of ſtrong *dolphins* on the weſt ſide of the channel in the middle of the river; and continuing the line lower down, and increaſing in number thoſe that are on the eaſt ſide. This meaſure, independent of every thing elſe, would be a great ſecurity againſt diſturbance, both from land and ſea. However, if the magiſtrates are inclined to begin a jetty or break-water from the S. W. point in or near the direction ſpecified in the plan, in order to try the effects of it, I would not be underſtood to diſcourage the attempt; and if not carried beyond the limits there ſpecified, I apprehend any ill effects that it might have upon the oppoſite bank might be guarded againſt. It may be begun with rice and rubble ſtones, and afterwards by ſinking old veſſels; or continued with the former materials, as ſhall appear in the execution beſt to anſwer the end.

I come now to the ſubject of the banks: and on this head, as I have already declared that my opinion is in general, to diſcourage all attempts to prevent the free influx and efflux of the tides and land waters, in order to preſerve the channel out to ſea in the moſt effectual manner, upon which both the navigation and drainage dependent on the *Ouſe* entirely hinge; nothing remains to be done with the banks, but to make them ſtout enough and high enough to ſtand againſt all extremes: my buſineſs will therefore be, to ſhew how this is to be effected. To give directions about the particular parts would be endleſs, and will be the proper buſineſs of the ſurveyor, who ſhall be entruſted with the execution thereof; I ſhall therefore content myſelf with ſhewing the general principles, which will eaſily be applied by the judicious artiſt to the particular caſes.

In the firſt place, I entirely diſapprove of all jetties built into the ſtream, as a defence for ſaving the banks or foreſhores from the action of the water, as I am convinced from many obſervations that they have a direct contrary tendency; for they ſeldom fail of producing a deep pit, either oppoſite to, or on the downſtream ſide of the jetty, which

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tends to undermine the banks, and even the jetty itſelf; ſo that thereby the *rent is made worſe.*

Whatever works are attempted for the preſervation of the foot or banks of foreſhores, when too hard a *ſet* of the water tends to undermine them, ought to be diſpoſed parallel, or according to the direction of the ſtream; ſo that the water, inſtead of being ſtopped or thrown off, ſhall glide gently by, with the leaſt interruption poſſible; for thereby the water gets away with the leaſt poſſible action upon the banks, and conſequently wears them or their defences the leaſt. For this reaſon all angles and ſudden turns are to be avoided as much as may be, and where a turn muſt be made, as very frequently happens, let it be made with as eaſy a ſweep as poſſible, keeping it as near as may be the ſame with the natural, that is, the general *bend* of the river, cutting or rounding off all ſmall ſudden turns, angles or extuberances, which may happen in the general ſweep; which directions will hold, as well for forming the baſe and middle lines of the artificial banks themſelves, as for preſerving the foot of the natural foreſhores, whereon the other is founded. To act otherwiſe is to oppoſe a natural current, and to oppoſe a natural current is to give it ſomething whereon it may inceſſantly act, towards the deſtruction of the oppoſed work; which in the caſe of banks and their defences, is to do ſomething contrary to the very intent of doing it.

This doctrine cannot be better illuſtrated than by the two great jetties, in the turn above the *Ball-fleet*, oppoſite and juſt below which are five and ſix fathom water; whereas the natural bottom or depth is not more than as many feet. By this means their foundations are ſapped, as well as the adjoining banks, which in conſequence muſt be ſubject to very expenſive repairs, as the bite of the river will grow deeper on every alteration.

This is alſo the caſe with a number of jetties on the weſt ſide of the river below the ferry: to ſay the truth, I ſcarcely ever ſaw an inſtance where this ſort of works, when applied as a defence to the banks, did not do miſchief; it would be very well that they were all removed, or if this is thought too much expenſe, at leaſt never more to be repaired in their preſent form.

Where the ſides of a river or foreſhores grind away by too great ſtreſs of water, the moſt infallible, ſecure, and laſting method of doing it is, after the ſudden extuberances and irregularities of the curve are taken off as low as the water will admit of by hand, to line up the foot with rubble ſtones, thrown in promiſcuouſly, ſo as to

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form their own natural ſlope againſt the ſhore, till they appear above water, at low water. This being done for the whole length of the galled place, with the regularity before deſcribed; and being further ſupplied with a freſh quantity after a ſettlement has happened, in conſequence of ſucceeding great tides and floods; will prove a laſting ſecurity againſt further depredations at the foot; and the foot being well ſecured, Nature will, in moſt caſes, where there is room to do it, form of herſelf ſuch a natural ſlope to neap tide high-water-mark, as will need no artificial defence. The chalk and clodlime rubble that is brought down the river, ſeems a very good material to be employed in this way, but the rubble of any ſtone that will bear wet and dry will do, which can be procured cheapeſt; the larger and more irregular, both in point of ſhape and ſize, the better.

The ſame defence, where ſtone is wanting, may be procured by the application of ſtakes and rice; but diſpoſed, as before directed, even and parallel to the ſtream*, without jettings or extuberances; but nothing can be done with theſe materials comparable to rubble ſtones, on account both of want of weight and duration.

It may poſſibly be objected, that a ſufficient quantity of rubble ſtones, to ſecure the foot of the banks and foreſhores in this manner, will be expenſive; and in ſome caſes poſſibly it may; but it muſt be conſidered, that here will be no expenſive tide-works, with a number of men, and that there will be very little additional charge beyond that of bringing down the ſtones; but in preference to all methods that are in themſelves ineffectual, the cheapeſt way is to do nothing.

The baſe of the bank and foreſhores being ſecured as above deſcribed, it has already been ſaid, that where there is room enough, Nature will herſelf form a ſlope upon the foreſhores up to the high-water-mark of neap tides, which will be of itſelf a ſufficient defence againſt waves and currents; and where there is no want of room to form a ſufficient ſlope above the neap tide high-water-mark to the top of the bank, there is no better way than to ſlope and turf it over, in the manner that has already been put in practice, but above and below the town of *Lynn*; and alſo on the other ſide of the water. I can give no better directions than theſe ſpecimens will afford, which ſeem done with great judgment; only that, inſtead of uſing any wood at the foot of the turf about neap tide high-water-mark, I would adviſe to rely wholly upon a *lay* of rubble ſtone; and if ſome of it is broken ſmall ſo as to fill up the interſtices of the larger pieces, this will form a more complete union between the rubble and the turf, than if compoſed of large ſtones only.

* The ends outward, and a little inclining down ſtream.

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Where the artificial banks ſtand ſteep upon the foreſhores, I obſerve that the practice about *Lynn* has been to defend them by a boarded wharfing. This at firſt ſeems to promiſe much ſecurity; but experience has proved that this is only *outſide*: and if we conſider the action of the waves upon it, we ſhall find this method not at all calculated to ſuſtain their ſhocks for any length of time, the very union of the parts being the cauſe of their deſtruction.

If the ſea daſhes againſt the end of a faggot or a ſtone, theſe having no ſolid connection with their neighbours, the impreſſion goes no further; but the tremors raiſed in one part of a boarded wharfing is communicated to the whole, or to a large area; which, accompanied with the great ſhocks that muſt unſue when a conſiderable part of the ſurface is ſtruck together, theſe agitations by little and little ſhake and looſen the earth behind, which by the riſe and fall of the tides is by degrees waſhed out at the foot and through the crevices, which brings the whole to ruin. This, accompanied with the ſpeedy decay of all wood work expoſed to wet and dry, makes it ſeem to me quite eligible totally to diſcard this method in all future repairs. In lieu whereof I would recommend the following: wherever the foreſhores are not broad enough from low water to neap tide high-water-mark, to ſtand by a natural ſlope, I would adviſe them to be reduced to a ſlope of two to one; that is, to batter two feet to one foot perpendicular; and this being covered a foot thick with rubble ſtone of all ſizes bedded together, and footed upon the rubble, ſuppoſed to be thrown in to ſupport the ground under low-water-mark, will, as I have often experienced, make a very laſting defence, and is capable of great reſiſtance in all ordinary caſes; but if expoſed to the waves of the open ſea, the cover muſt be increaſed in weight and thickneſs. This method will anſwer the end, if the batter is three to five, or even one to one; but the latter I would not recommend without extreme neceſſity.

With reſpect to the upper part of the bank, from the high-water-mark of neap tides, to the high-water-mark of the equinoctial ſpring tides; I would, in all caſes where it is poſſible, ſhift back the banks, till they will admit of the ſlope and turf method above referred to; but if this be not poſſible, to continue the ſame batter as the foreſhore, and to face the artificial banks with ſtone in the ſame manner as already deſcribed.

I do not know of any ſecurity againſt *inundations*, in a country that is defended by banks, otherwiſe than by making thoſe banks, not only ſufficiently ſtrong, but high enough to ſuſtain the greateſt extreams, without being overflown: and it is from *experience alone*, that theſe extreams are to be learnt.

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The greateſt extream of a flood or tide that has been known at *Lynn*, appears to have been one on the ſecond of *December* 1763, when the water flowed one inch deep in the compting houſe of Mr. *Elſden* of *Lynn*, and left a very viſible mark, which he ſhewed me. This mark ſhould at high-water of ſome ſpring-tide, be transferred to the Cuſtom-houſe, or ſome public place near the river, to which recourſe may conſtantly be had. Though this is the largeſt tide we know of, yet there are accounts of ſeveral tides within a few inches as high as this; I do not therefore look upon the banks to be ſafe, unleſs they are proof againſt ſuch another tide as this; and to this, as a ſtandard, I would conſtantly refer: I cannot, however, look upon them as *proof*, unleſs they are made up at leaſt one foot above the level of this mark, and maintained, after ſettlements, at the height of half a foot above the ſame. It is not, however, neceſſary, to preſerve the ſame ſlope above the high-water-mark of equinoctial ſpring-tides to the extreameſt height, as below that mark; becauſe they will but ſeldom come to a ſtreſs; yet when they do, they muſt be *ſufficient*, or they anſwer not the end.

In order to this, they ought to be three feet at leaſt broad at the extream height; and at leaſt three times as much broader at the level of the equinoctial ſpring-tide mark, as the extream height exceeds that height. The artificial banks below that mark ſhould be at leaſt four times as much broader, in their baſe or ſeat, upon the natural level of the ground, as the perpendicular height of the ſaid extream tide-mark is above the natural level of the ground, whereon each part of the ſaid bank reſpectively ſtands. Theſe proportions will be very ſufficient in the neighbourhood of *Lynn*, where the earth is good; but where the earth is looſe, ſandy or moory, the baſes or ſeats and tops ſhould be reſpectively broader.

Theſe are the beſt methods that I know of putting the town and country in a ſtate of ſecurity; every other attempt to leſſen the tides themſelves will not only be vain and fruitleſs; but even, if effected, hurtful to the general drainage and navigation of the country.

If the expenſe be objected to of making up the banks in this manner, I anſwer; that if we take the compaſs of a few years, it will be a great ſaving: but ſince this is the only permanent and ſecure method that I know of; if it is not worth while to put the properties into a ſtate of ſecurity, then the proprietors muſt be contented to poſſeſs them in a ſtate of inſecurity:

After having declared it as my opinion, that every attempt to check the free influx and efflux of the tides (that is, while it remains an open river) is likely to be hurtful to the ſcour

ſcour of the ſea channel; it ſeems natural to be aſked, if I do not look upon *Denver Sluice* in this light? I anſwer, that *Denver Sluice* is much too far up from the out-fall to work any conſiderable effect either way; but that the *natural* effect of it, as well as the hundred foot drain, ſo far as they operate on the harbour of *Lynn*, and ſea channel below, muſt be rather beneficial; as may be demonſtrated from a circumſtance mentioned in *Badſlade's* hiſtory, page 46, where, ſpeaking of the river *Ouſe*, he ſays, "The low-water-mark up "the river is much lower in neap than in ſpring-tides; whereas down to ſeaward, the "low-water-mark of a ſpring-tide is lower than that of a neap." This being the caſe, (which is not a peculiarity of this river,) it is evident that the ſpring-tide of flood, in the remote parts, could not get back again the ſame tide; but, inſtead of returning back, ſpent itſelf up the river, and in the fens, before that ſluice was built; it is therefore, at that length, more uſeful to check the tide of flood, in order to give it a better recoil, than to ſuffer it to ſpend itſelf in the fens at the ſpring-tides, and languidly to return in the neaps; without power in itſelf to operate, or to co-operate with ſuch a tide as would give it power. The cauſe, therefore, of the univerſal ſilting of the channel of the *Ouſe*, after the firſt erection of *Denver Sluice*, and cutting the hundred foot river, ſo univerſally and loudly complained of, muſt be ſought from other ſources, than a *natural* tendency of theſe works to produce this effect: but as this will lead me into a freſh and large field of matter, not immediately conducing to the buſineſs in hand, I ſhall forbear the purſuit of this ſubject any further at preſent.

I cannot conclude my Report without obſerving, that it ſtrikes me, that the ſureſt, and I may add the cheapeſt, way of putting the ſhips into a ſtate of *perfect* ſecurity, would be by building wet docks in the manner of *Liverpool*; for which, the ſituation of *Lynn* ſeems to afford a noble opportunity, particularly in the flat ground below the block-houſe.

J. SMEATON.

Auſthorpe,
14th *September* 1767.

APPENDIX.

APPENDIX.

Containing an Extract from a Pamphlet printed in the Year 1742, faid to be wrote by Mr. *Elftobb*; intituled, Some Thoughts on Mr. *Rofewell*'s and other Schemes, now propofed for amending *Lynn* Channel and Harbour; in a Letter to the Merchants, Owners, and Mafters of Ships, belonging to the faid Place.

GENTLEMEN,

THE prefent ftate of your channel is now not only become the common topic of converfation, but alfo the laudable care of the magiftracy, whofe ready difpofition to do fervice to the town, is evidently manifefted by the early fteps they have taken in this affair; in confequence of which, Mr. *Rofewell*, by order of the honourable the commiffioners of the navy, has lately infpected the harbour and channel to feaward, down as low as the road, and has propofed a method, to remedy the evils, which he obferved at prefent to attend them, and to prevent their growing bad for the future.

But as I think the remedy he propofes, will not remove the evils he complains of, but will rather increafe them; fo I cannot forbear giving you my fentiments thereupon, tho' without any defign of depreciating that gentleman, who I doubt not is fufficiently judicious in things of this kind. But as he came an entire ftranger to the place; and as I am informed, took but a tranfient view of it, and formed moft of his fentiments, from the information of people, prejudiced in favour of particular notions and opinions concerning the thing, it is not to be wondered at, that he is fo far wide of the matter.

His opinion it feems is, that *the badnefs of the channel to feaward, is owing to a bar of fand, lately grown up crofs the eaft channel, about three miles below the crutch-point.* And he fays, he is informed, that *the faid crutch-point on the eaft, and the point on the weft fide of the harbour's mouth, formerly landlocked each other, by which means the harbour was preferved in a great meafure from the fury of the north-weft winds, and flood tides, was rendered fafe, and the channel maintained deep and good; but by the continual force of the faid winds and tides againft the weft point, and by the violent action and force of the fouth-weft winds and ebb-tides, againft the crutch-point, on the eaft fide, both thefe points of land are now much fhortened, and the harbour laid more open; fo that the fury of the north-weft winds tears down the marches, endangers the banks, and threatens the ruin of fome of the lands on the eaft fide of the river, between the block-houfe and the crutch; the confequence of which may be* (he fays) *the entire lofs of the harbour. Befides, fince the points are thus become open,* (I think he fays), *it occafions the flood to form an eddy, by which means the filt fubfides, and has formed the bar which he fo much complains of.*

The

The remedy therefore which he propofes is, to *erect two jetties, or wooden piers, one on the weft-point, to ftretch over to the eaftward; and the other on the crutch-point, to ftretch itfelf to the weftward; and fo to landlock the harbour, as it formerly has been.*

By this means (fays he) *the harbour will be preferved from the violence of the north-weft winds and flood tides, will be rendered fafe and quiet, the eaft-channel recovered and the bar be fcoured away.*

This, gentlemen, is his opinion, and the remedy he propofes. And now, with all due fubmiffion, I fhall beg leave to give you my fentiments thereon.

'Tis to be obferved, that in the prefent ftate of the harbour and channel, there are but two evils which have fallen under his notice.

The firft is a bar of fand on the eaft channel, three miles below thefe points, which bar he fuppofes to be lately grown up, and formed by means of an eddy in the-flood tides, occafioned by the fhortening or opening of the faid points. But how the alteration of the ftate of thefe points could any way form fuch an eddy as to occafion a bank of fand in the channel, at three miles diftance, is to me quite unconceivable. Befides, the bar is no new formed thing as he fuppofes, but is of old ftanding, as is well known to the gentlemen navigators; tho' 'tis not always in the fame ftate, but often fluctuating and changing: being fometimes higher, fometimes lower, according as feafons have proved wet or dry, and the quantities of the ebbs and back-waters have been greater or lefs. Thus, in fome very wet feafons, it has been almoft worn away, and the channel for a while maintained good; and in dry feafons again, it grows up, and the channel becomes bad; which has lately been the ftate of it, tho' now by the increafe of the back-waters 'tis already much mended. However, let the duration of it, and the formation of it be as they will, the removal of it is the thing.

And this I believe every one will agree muft be effected, by the ebbs and back-waters, which fhould be convey'd as entirely, unitedly, and directly to it as poffible, fo that they may exert their whole undiminifhed force and power thereon, without meeting with any ftops or impediments in their way. For the force of water in fcouring away a fand, or deepening a channel, is always proportional to the quantity acting in a given time, and the vigour or force with which every equal part of that quantity does act. Thus, for inftance, if a tun of water was to pafs over a fand in a minute's time, and every gallon of that water exercifed a force on that fand, which may be reprefented by 1 or unity, then the whole force exercifed in a minute's time upon that fand, may be reprefented or expreffed

by

by the number 252. But if the quantity of the water acting in the ſame time be doubled, and the force with which every gallon acts, be doubled alſo, as it will be if the velocity of the current be doubled, then the force which the water exerciſes upon the ſand in a minute's time will be four fold what it was before, and in this caſe may be expreſſed by the number 1008.

What then can we think of this gentleman's jetties, which, inſtead of conveying the back-waters and ebbs directly to the bar without obſtruction, muſt neceſſarily divert them from it, and turn them over to the weſtward, giving them ſuch a courſe as will direct them much more into the weſt channel, and cauſe them to ſtrike more directly againſt the breſt ſand than at preſent, and ſo both leſſen the quantity acting, and alſo the force with which every proportional part does act; ſo that if the bar increaſes and grows upon us now, we may then expect the decay of the eaſt channel will be much accelerated; for ſure 'tis not a little abſurd to imagine, that turning the courſe of the ebb-water more to the weſtward, can promote the removal of a ſand which lies in the eaſt channel, or any way deepen or mend that. Too much of the ebb-water does already go down the weſt-channel, which lies too *directly in its preſent courſe*; but if its direction be changed ſtill more to the weſtward, as it certainly will be by theſe jetties, then the principal part of the ebb-water will be turned into that channel, and other ſlade ways, which can afford it a paſſage to the weſtward; and the eaſt channel will be almoſt deſerted, and left almoſt dry every ebb, and conſequently in a little time would choak up, and be entirely loſt.

So far then is the method this gentleman propoſes from being a certain remedy to the eaſt channel, that in all probability it will be the utter deſtruction of it. And thus much for the firſt evil he complains of.

The other evil is, the waſhing away of the marſhes, and the danger of drowning the lands on the eaſt ſide.

This (I ſhall beg leave to obſerve) is a thing which more immediately concerns the land-owners than this corporation. The ſecurity of their eſtates is certainly as much their own proper concern, as the ſecurity of thoſe on the weſt ſide is the proper concern of the owners of them. But (ſays this gentleman) *the drowning of theſe lands will be the ruin of your harbour.*

This I muſt confeſs I do by no means apprehend. Suppoſe that two or three hundred acres of theſe lands were every tide laid under water, not one gallon the leſs water would flow up the river than does at this preſent, and all the waters, which would then cover theſe

theſe lands in the time of flood, would be an additional quantity to return in the time of ebb, which would certainly very much help to ſcour away the bar, and maintain a good channel. But ſuppoſe that the ſecurity of the harbour does depend upon the preſervation of theſe lands, are theſe jetties like to be effectual for that purpoſe? I conceive not. 'Tis true, they will leſſen the beat of the tides during the time of high-water, which by the opening of theſe points, when the north-weſt wind blows, is now very great, and waſhes away the ſurface, and turf of the land very faſt; this I ſay would be in a great meaſure prevented. But then the flood-tide would be carried continually and directly into the crutch-bite, and ſo would the ebb alſo; and by the continual and violent action of both, the lower ſhores would be ground away, and the bite extended more and more to the eaſt-ward, and the lands and banks will be as effectually ruined by the undermining of the ſhores, as by the waſh and beat of the waters upon the ſurface; tho' perhaps not altogether in ſo ſhort a time.

Now, as I think this will certainly be the conſequence of this ſcheme, ſo I thought it an incumbent duty to apprize you of it, that you, whoſe intereſts depend upon the preſervation of the navigation of this port, may make proper repreſentations againſt it.

I know ſome gentlemen are mightily alarmed at the wearing away and opening of the two forementioned points, as if the ruin of the harbour muſt immediately enſue, and as if the goodneſs of the channel entirely depended upon the projecting or extending of theſe points. But it may be remembered, that ſome years ago, while *Denver* ſluice was ſtanding, and the reception of the flood leſſen'd, and the back-waters prevented from coming down, the quantity of the ebbs was then ſo ſmall, that it was all carried off by the weſt-channel, and the eaſt-channel was ſo deſerted, that at low water it was left almoſt dry, which made it ſoon grow ſo ſhallow, that at the time of high water, there was not water ſufficient for any loaden ſhips, all which were forced to go round at the back of the ſands, and come through the weſt channel up to town; and at that ☞ time theſe points were both far extended, and landlocked the harbour. 'Tis therefore very evident, that the goodneſs of the channel does not depend upon the extenſion of theſe points, nor do I apprehend that there is ſuch imminent danger from the opening of them, as ſome are inclined to think.

The channel is now in as good a ſtate as it commonly has been in for ſome years. And if we ſhould in a little time have a continued wet ſeaſon, which may happen, it will quickly be much mended. And I think it is much the better way, to truſt to nature for a remedy, than to execute at a great expenſe ſuch ſchemes as in all probability will be very pernicious and hurtful to the channel.

Some

Some gentlemen it ſeems do plainly diſcover the impropriety of Mr. *Roſewell*'s ſcheme, but yet think ſomething ought to be done for the preſervation of the lands, and the amendment of the channel, and therefore are for erecting a jetty croſs the crutch-bite, all along the eaſt ſide, towards the block-houſe; and another jetty on the weſt-point, to extend this point more over to the eaſtward.

The firſt, certainly, ſo long as it ſtands, if made ſufficiently high, will be a great ſecurity to the marſhes, and lands on the eaſt ſide, and would prevent both flood and ebb from encroaching on that ſide, and likewiſe aſſiſt them in ſcouring away that pernicious point of ſand, which extends itſelf from the weſt point, ſo far over to the eaſtward, into the crutch-bite, for though the turf and vegetable ſoil at the weſt point are much waſhed away and ſhortened, the ſand ſtretching from that point is by that means much lengthened, and determines both the flood and ebb more over to the eaſtward than before; and ſo far will it be from doing ſervice to the channel, to extend that point, that if the vegetable ſoil was only ſecured in its preſent limitations, and the point of ſand intirely ſcoured away, it would certainly be much better for the channel, for then the ebb would not be ſo inclinable to go down the weſt channel, but would proceed more directly to the bar, and act upon it with much greater force than now, and conſequently keep it lower, and maintain the eaſt channel better; and then perhaps the weſt channel might gradually grow up. And happy would it be for *Lynn,* if that channel was intirely ſtopped up, for it is the quantity of ebb that goes down that channel, that ſo weakens the current in the eaſt channel, that inſtead of ſcouring away the points of ſand which project into it, it is ſtopped and retarded by them, and formed into vortices and eddies, which throw more and more ſilt upon them, and in ſome places (as at the bar) extend them quite croſs the channel; for it is by this means, and by the flood-tide coming up the weſt channel, and forming an eddy at its entrance into the eaſt channel, that the bar ſo much complained of is formed: for it is obſervable that this bar lies not far below the mouth of the weſt channel, juſt about the place where one might expect ſuch eddies would occaſion it.

A jetty therefore at the weſt point, ſeems to me quite wrong, and I think will be very hurtful. If therefore a jetty muſt be erected, I would adviſe it, not upon the weſt point, but about a furlong to the weſtward of it, to extend itſelf to the northward, along the eaſt part of the breſt ſand. This would allow the ebb to ſcour away the ſand, that ſtretches from the weſt point and turn it more directly down the eaſt channel, towards the bar; and would at the ſame time very much ſecure the eaſt ſide from the violence of the weſterly and north-weſt winds, and be a great ſhelter to the harbour too from theſe winds.

And

And if the weſt channel could be ſtopped up, by the ſinking of old hulks loaded with ſtones, or any other means, ſo that the ebbs might be prevented from taking their courſe that way, we might then have great hopes of maintaining the eaſt channel, in a much better ſtate than it has ever yet been in.

But as ſome gentlemen are apt to imagine, that a jetty on the weſt point, by turning the ebb-water more over to the eaſtward, will direct it more into the eaſt channel, it muſt be acknowledged that it would have this effect, if this channel were ſituate to the eaſtward of that point. But the eaſt channel itſelf is ſituate far to the weſtward of that point, and conſequently the more the ebb is carried to the eaſtward by the jetty on its ſouth ſide, the more weſterly muſt be its direction on its north ſide, to arrive at that channel; and when once it has received this weſterly direction, the weſt channel and other ſlade ways lie ſo fair to receive it, that in all probability very little of it will go down the eaſt channel.

The way then to direct it down the eaſt channel, is not to turn it more to the eaſt at the weſt point, it going far much to the eaſtward at that place already; but the way muſt be to let that point of ſand wear away, that it may take its courſe more in a direct line for that channel. Some may object, that the wearing away of that point will lay the harbour more open, and make it more turbulent and unſafe than at preſent. But in anſwer to this, a jetty from the weſt marſh, to extend northward, along the eaſt part of the breſt ſand, will in a great meaſure prevent that. However, it is to be obſerved, that the ſecurity of the harbour, and the goodneſs of the channel, are two different things, and what procures one, may be pernicious to the other. The goodneſs of the channel will be promoted by the quantity of water that comes into it, and flows through it, but the greater the quantity of water, the greater the agitation, and the more turbulent. On the contrary, the leſs the quantity of water, the leſs the agitation, and the quieter the harbour, but then the worſe the channel. When ſuch works are undertaken, therefore, the end and purpoſe ſhould be well conſidered, and things inconſiſtent in themſelves ſhould not be purſued at the ſame time.

However, it is not to be expected, that theſe, or any other means, can render the channel *conſtantly* and *unchangeably* good, ſo long as its courſe lies betwixt and amongſt ſuch looſe and moveable ſands. A rage of winds and tides, or an extraordinary time, either of drought or rain, will occaſion great alterations in it, ſometimes for the better and ſometimes for the worſe, becauſe even when the back waters are the ſtrongeſt, and ſo the moſt likely to preſerve a good channel, they will ſometimes ſcour away the ſands in one place, and let them drop in another place, where they may be more prejudicial to the channel than before; and thus will the ſtate of the channel be always liable to changes and alterations.

WELLS HARBOUR.

(See the Plan, Plate I. of this volume, Fig. 2.)

The REPORT of John Smeaton, Engineer, upon the State and Condition of *Wells* Harbour in the County of *Norfolk*, and how far the same may be affected by the Imbankment of the Slade Marshes.

HAVING carefully inspected the present Condition of the Harbour of Wells in the county of Norfolk, and the Slade Marshes, and other premises, the object of a suit wherein Sir Martin Brown Folkes Baronet, and Robert Hales Esq. were plaintiffs, against George Chad Esq. and other defendants, and having also carefully inspected the several Plans and Papers that have been produced in evidence in the said cause, the following facts drawn from my own view of the premises, and in part from the evidence produced, appear to me to be very well ascertained and agreed upon.

1st. That the harbour of Wells has of late years grown into a worse state than it formerly was in, and particularly since the imbankments that took place in and about the year 1719; and,

2d. That for remedy of the complaints that then subsisted in the harbour, in the year 1738, a work was constructed that had the name of Freestone's Sluice, so called from the projector or builder thereof, whose name was *Freestone*.

3d. That this work had a beneficial effect in scouring away the mud and sand that annoyed the Harbour and channel from the mouth of the said sluice, down as far as the Pool.

4th. That at that time, that part of the channel called the *Pool* was so deep, that at low water two or three tiers of vessels could lie afloat, and swing round.

5th. That in the year 1758, the last imbankment was erected, which is the matter now complained of, and is the object of the present suit.

6th. That

6th. That the extent of ground inclosed, and defended by the said imbankment, is nearly 17 acres in the East Marshes, and 47 in the Slade Marshes, together making about 64 acres, besides and interspersed in which are creeks formerly and now containing water to the amount of about three acres, making altogether a surface of about 67 acres, or thereabouts.

7th. That besides the above, there is not only a much greater quantity of imbanked lands, which was chiefly taken in about the year 1719, but still a much greater quantity than all the imbanked land put together, still remaining unimbanked, over all which the spring tides *usually* flowed before the imbankment, but the neap tides *rarely*, and which now is the case with the greatest part of the unimbanked marshes.

8th. That no fresh water river makes its way to sea through the channel of the harbour of Wells, nor indeed any considerable quantity of fresh water of any denomination; and that not only the channel that forms the harbour, but the several branches and creeks into which it is divided (as is particularly distinguished in the map made by Beiderman under the direction of Mr. Mylne) are all supplied with sea water on tide of flood, which reflowing back to the sea on tide of ebb, thereby forms a *back water* and produces a *scour* that tends to keep the channel of the harbour open.

9th. That in the year 1765, Freestone's Sluice having been originally constructed in a slight manner with fascines, stakes, piles, &c. the mouth thereof was so much widened, that its effect having been for some time past greatly impaired, another was built upon a new site, which when erected, reproduced the same effect, as to clearing the harbour and channel down to the Pool.

10th. That the sluice of 1765 which had been constructed with greater strength and care than that of Freestone, though upon the same model, in the year 1777 was found to have been nearly destroyed by worms; on which occasion Mr. Wooler was called in to advise the commissioners, who reported his advice to build a new sluice in a new situation, upon a new construction, and with such materials as the worm could not touch.

11th. That on account of the expense estimated by Mr. Wooler at £2,000, this work was not undertaken, but in lieu thereof, proceedings were gone into that terminated in the present litigation; on supposition on the part of the commissioners, the defendants, that the taking down the East Marsh Bank, whereby the tides would be readmitted upon the surface of the 67 acres before mentioned, would reduce the state and condition of the harbour in every respect, or in all the most material respects, to what it was before the erection of that Bank in 1758.

12th. That however, the Sluice since Mr. Wooler's report has been repaired, and it appeared at the time of my view to be of the same construction that it had formerly been, according

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according to its deſcription, and tending to produce the ſame effect, which it is reported to have formerly done.

13th. That during the whole interval ſince Freeſtone's Sluice was firſt conſtructed in the year 1749, to the preſent time, the operation of the ſluice has conſtantly been (when in order) nearly the ſame, viz. that of clearing and keeping in the ſame good condition nearly all that part of the harbour and channel that lies between the mouth of the ſluice, and the upper or ſouth end of the Pool.

14th. That during a period of years ſince the year 1749, the Pool has been filling up, or growing ſhallower, inſomuch, that at low water, at the time of my view, there was not above ſix feet water.

15th. It further appears from evidence, that for a long period of years preceding all the imbankments herein mentioned, the outfall or mouth of the channel of the harbour has lain very conſiderably more to the weſtward than at preſent, and that it has from time to time changed more to the eaſt.

16th. That formerly, that is, within the compaſs of 20 years, the direction of the channel out to ſea was N. W. and that at that time the flow of the tide being in the direction of the channel, during all the time of tide of flood, it was very eaſy with a proper wind to bring veſſels from the ſea through this channel into the pool and harbour.

17th. But that ſince the channel has come more to the eaſt, and the direction gradually veered about, ſo as to have come now to a N. E. or N. E. by N. direction, as it was at the time of my view, it is a fact, that whenever the tide has riſen above the ſurface of the Broad Sands, the tide ſtill keeping its former direction from N. W. to S. E. drives the veſſels acroſs the channel upon the eaſtern bank or ſand, and therefore without a ſtrong leading wind veſſels cannot enter without danger, and in fact ſince theſe changes have taken place, many ſhips have been loſt, notwithſtanding the ſkill of the pilots, to the no ſmall diſadvantage of and diſparagement to the port.

18th. That the diſtance from the quay to the outfall of the channel is at preſent betwixt three and four miles, and that the channel both now lies and ever has lain, through large broad open ſands, from the northward or out end of the pool to its outfall into the ſea, which ſand being perfectly clean, and free from all particles that might create tenacity, when dried by the ſun is capable of being blown by the wind, and moved by the common agitation of the ſea, and very conſiderable changes are wrought by the action of the ſea in great ſtorms and tempeſts; and that this is the deſcription of the ſands in general that lie many miles extended on this coaſt.

19th. That

19th. That the breadth of this ſand, or diſtance from the pool to low water mark, has conſiderably increaſed within the memory of man.

20th. That the channel from the *Shelf* without the north part of the pool to the ſea has now as much, and about the ſame draught of water or flow of tide at high water, as it has been known to have in man's memory.

21ſt. That the port of Wells is of great conſequence not only from its ſituation with reſpect to the ſurrounding country, but alſo from the traffick ſettled in the place, and therefore that nothing ought to be done that can be of real detriment thereto.

I have thrown together the above leading facts not only for my own eaſe in compoſition, by avoiding more tedious deſcriptions, but that from this general view of the ſtate of facts, I may be the more readily followed in my reaſonings thereupon.

From the above there naturally ariſe the following queſtions:

1ſt. What is the natural cauſe of the decay of the harbour of Wells?

2d. Whether the imbankment in queſtion made in the year 1758 have materially contributed thereto?

3d. Whether the removal of that imbankment will contribute to a material amendment thereof?

Queſtion the firſt.—What is the natural cauſe of the decay of the harbour of Wells from what it has been in former times?

To have a clear and comprehenſive view of the cauſe of *decay*, it will be neceſſary to ſhew the natural cauſes by which the port of Wells has been *formed*.

We are all appriſed that notwithſtanding the annual downfalls of rain and ſnow upon the land, which run into the ſea in every part of the habitable globe, the quantity of water contained in the ſea is never the *greater*; and this may reaſonably be expected when we conſider that the exhalations which form thoſe rains and ſnows, are chiefly raiſed from the ſea by the power of the ſun and winds.

The floods and torrents that make their way from the ſurface of the land, in conſequence of the rains and ſnows, take along with them great quantities of clayey, earthy, and ſandy matter (intermixed with many other kinds of matter, which it is needleſs here to enumerate)

enumerate) down into the channels of the rivers, and are by the violence of the torrents carried to the ſea, and there in appearance diſperſed.—Theſe kinds of matter, not being capable of being raiſed again, and returned back to the land, as the water is, it neceſſarily follows that the quantity of ſandy and earthy matter that is depoſited in the ſea, is in a continual though apparently very ſlow ſtate of increaſe, and by the conſtant flux of the tides, and the agitation of the winds, thoſe materials ſo depoſited are capable of being removed from the parts adjacent to their entry into the ſea, not only to the neighbouring, but even to very diſtant parts; and though the remarkable quantity of ſandy ſoil in the county of Norfolk may in part account for the vaſt quantities of ſands upon the coaſt thereof, extending as it were in one continued chain from the coaſt of Lincolnſhire, very much infeſting the great bay between the two counties called the *waſh*, and ſtill extending coaſtways far beyond the port of Wells, even to Cromer, as I have been informed, yet it is by no means neceſſary to ſuppoſe that they have *all*, or in the greateſt meaſure, proceeded from the land of the two counties, to the coaſts of which they now lie contiguous; they may as well have proceeded from parts far more diſtant, and that brought hither by the inceſſant action of the winds and tides, they find a place better adapted to their reception and repoſe than thoſe from whence they came; and indeed it may alſo be as well ſuppoſed that they may in *part* have come from thoſe coaſts which by the particular ſet of the wind and tides have been *waſting* for ages paſt, as to ſuppoſe that they all proceed from the high lands of any place or kingdom whatſoever.

It is however of no conſequence to our argument to point out *whence* they came; it is ſufficient that they have come, and that being here depoſited, and finding it a place where they are leſs liable to be carried away than they were to be brought hither, the quantity upon the whole muſt increaſe, and ſince there appears no power of nature by which they can be returned to the high grounds, or coaſts from whence they were brought, it muſt follow that they muſt continue to increaſe, till ſome contrary power of Nature ſhall take place that we are not acquainted with, or the place of their reception become entirely filled.

It follows then that the attachment of ſandy and earthy matter to this coaſt is *in a progreſſive ſtate of increaſe*, which it is as much out of any human power to prevent, as it is to prevent the ſandy and earthy matter from being waſhed down from the high grounds into the ſea.

We need not therefore extend our views further to be enabled to ſee clearly, that in ſome former age, that is, in ſome ſtate of the progreſſion of this work of Nature, there was a time, when nothing more than a naked ſand lay againſt the bare coaſt of the elevated

elevated ground upon which the town of Wells now ſtands, which we may ſuppoſe ſimilar to that which now lies between *Wells Miels* or *Marram Hills* and the low water at ſea, which being upon one regular decline, the tide water can flow and reflow over the ſurface without channel or creek; and in this ſtate, as there would be no harbour, there would not on that account be need of a town: but let the breadth of the ſand gradually increaſe to double, and then the declivity would become too ſmall for the tidal water left by the flood to make its retreat ſo as to keep pace in its return with the ebb at ſea; and therefore a body of water being thus left behind, and having a ſenſible declivity towards the ſea, would naturally make its way into the loweſt ſlades, and there cut a *gully*, which (if not formed gradually as may be ſuppoſed) would ſoon be enlarged by the influx and efflux of the tide; and thereby a ſcour would be produced through this paſſage enough to keep it open, in a degree ſufficient to let the water in and out, till it became ſo quiet as in a manner to ceaſe the operation of ſcouring; but the breadth of the ſands gradually increaſing, a greater body and ſurface of water will want a paſſage, and the power of ſcouring will increaſe with it; the gully will therefore by the ſame ſlow degrees enlarge to a *creek*, or *fleet* as it is here called, and leſſer ones will be formed to conduct the water more readily into the larger.

The natural progreſs attending this operation is, that the parts of the ſand furtheſt diſtant from low water, being leſs liable to agitation from winds and tides, the ſand intermixed with the finer particles of earthy and clayey matter brought in by the tides, are the moſt readily and quietly lodged there; and particularly the earthy and clayey particles will find a reſting place, which binding the ſand together, the whole will continue to riſe, till at a certain height, and in conſequence of a certain length of time of abſence of the ſalt water each tide, and expoſure to the ſun and air, the ſurface becomes fitted for vegetation, and by degrees will grow a certain ſpecies of graſs, and become a ſalt marſh; the graſs again entangling and locking up the earthy matter, will cauſe it to continue to riſe, and in an increaſed ratio, as the water upon the plain graſs ſurfaces becomes more ſhallow, and in conſequence more ſtill, and free from the agitation of external diſturbing cauſes.

During this period, as the marſhes have increaſed in height, they have alſo increaſed in breadth, and in conſequence a greater body of water will be left upon them; the gullies and creeks therefore, as they multiplied in number with the increaſe of breadth, the larger ones would increaſe in ſize and depth, and if all were ultimately collected into one, as has been the caſe with the channel of Wells Harbour, the ſcour would be ſufficient to maintain a channel through which veſſels might be brought from the ſea, and thus

thus an useful Harbour would be formed, which would increafe in depth and utility by the continuance of the forming powers, but yet, only to a *certain degree*.

I have faid that, as the marfhes increafed in breadth and height, more water wanting a paffage to the fea would be left upon them; and this, fo far as regards breadth, is felf-evident; but as the increafe of height diminifhes the depth of water upon them at high water, that the quantity left behind upon the whole will be greater, needs fome explanation. In refpect to this, it is obvious to every one who views the fubject, that while the depth of water upon the marfhes is confiderable, the water makes its way to fea by fettling gradually, and paffes off in the neareft direction over the marfh furfaces, without having any need for the gullies and creeks as drains; it is therefore perhaps only the laft half foot that may need the gullies; which, however, being limited to fome certain thicknefs (be it half a foot more or lefs), and this thicknefs much lefs than the depth at high water, the quantity fo left will be in proportion to the quantity of furface; and the number of gullies, being alfo in proportion to furface, the aggregate of the whole and the fcour thereof in the laft channel will alfo be proportionably increafed; it is likewife remarked, that in fact, the fcour is not very material till the water upon the marfhes has ebbed near their furface, that is, until it is juft retreating into the gullies, when the principal fcour begins.

Under thefe circumftances, the fcour would increafe and confequently the goodnefs of the harbour of Wells would naturally improve, while the neap tides covered the furface of the marfhes; but as the fame progreffion would in time caufe the furface of the falt marfhes to rife above the ordinary neap tides, the fcour would then begin to diminifh, becaufe, being not only deprived of the efflux of the water from the grafs furfaces into the gullies a number of times in a fortnight, the fcour of thefe gullies becoming immediately lefs, they would themfelves begin to choak up, and contain lefs *following* water; and therefore, in both refpects, the fcour being diminifhed in each particular gully, the fcour of the whole muft diminifh.

It is moft probable that this harbour, from the flow progrefs of the changes above fpecified, may have continued in a very flourifhing ftate for a long term of years, reaching backward beyond all record; though it is likely that for a part of that time it may have been in reality in a ftate of decay, and which we will now fhew will naturally refult from the fame progreffion of caufes that carried it to its *maturity*; fo that after having clearly feen from what natural caufes the Harbour has been produced out of the fea without a frefh water river to give it birth, we fhall then fee the natural caufes to which its *decay* muft be attributed.

From

From what has been laid down, it will appear moft manifeft that the rifing or elevation of the furface of the falt marfhes, by a frefh acceffion of fea mud which they will acquire more or lefs every time they are overflown, will not ftop at the *neap tides*, but will gradually rife higher and higher towards the high water of fpring tides; and if after that they were only to be overflown in the great fprings or raging tides, yet as every one of thefe tides will depofit fomething, they will ultimately be fhut up at the height of the extreme high water, though no *imbankment* whatever was to take place; and this will alfo happen in fucceffion to the gullies, creeks, &c.

For as the furface of thefe marfhes rifes higher and higher from the neap towards the fpring tide mark, they will be lefs and lefs often overflown, and the gullies made by the reflux of the tidal water from their furface will become lefs and lefs capacious, and in confequence of a want of reflow, the creeks will fuffer the fame fate, and laftly, the *fleets* and *main channel*: But as the tide water flowing in through the channel, fleets, creeks, and gullies, to the feveral extremities of its branches muft flow back the fame way, it is the extremities that will be firft landed up, becaufe every part betwixt fuch extremity and the fea will have water beyond it to flow over or throught it, and thereby producing fome degree of a fcour, will keep open a paffage either greater or lefs, while any water can get beyond it; and hence we muft expect, that the parts of the channel moft diftant from the fea will be thofe that in a ftate of nature will fooneft lofe their depth and capacity, till progreffively, from the extremities towards the fea, the gullies, creeks, fleets, and main channel will become folid land: and fo far it appears from teftimony, that long before the imbankation in the year 1758, nature had got on fo far in its progrefs in the decay of Wells Harbour, that it was much complained of; and the upper part between the quay and the pool was got fo bad, that the goods were in general lightered up to the quay, and that for remedy thereof, Freeftone's Sluice was built in the year 1749, which produced a good effect in clearing that part of the Harbour. As then it plainly appears from the preceding difcourfe, that the progreffion of nature has no tendency to cure the evils complained of, but ftill to increafe them, they are in confequence incapable of any remedy, except what can be applied by the ingenuity and labour of man.

We now come to the 2d queftion, whether the imbankment made in 1758 has materially contributed to the decay of the harbour of Wells?

From what has preceded it has been clearly fhewn, that as the keeping open and maintaining the channel entirely depends upon the reflow of the tide water, or *back water* as it is called, whatever cuts off and diminifhes this, muft be a detriment to the fcour, and confequently to the maintenance of the channel; I therefore do not hefitate in faying that

that all the imbankments both eaſt and weſt of the town of Wells, the water received upon the ſurfaces of which, and into their gullies and creeks, uſed to make its way back to the ſea by the channel of Wells Harbour, muſt have co-operated with the progreſſion of nature, and thereby tended to bring on more ſpeedily a general want of depth, which, as it has been already remarked, will be firſt perceived at thoſe parts of the tidal flow the moſt remote from the ſea; nay, we may go ſo far as to ſay, that if a bucket of water were taken up in the upper part of Wells Harbour, and not ſuffered to reflow, it might prevent the diſplacing of ſome particle of matter that had been lodged therein by ſome preceding tide. In this ſentiment I ſuppoſe every able engineer and ſkilful perſon that has viewed the premiſes will join as a *general opinion*, but though very true as a general ſentiment, yet the whole merit of the queſtion depends upon the *quantum*, the *how much* damage could reſult from thoſe artificial means; and as in this it appears that the opinion of different men have widely differed, I will proceed to ſtate my own with all the preciſion and clearneſs I am able.

Now, if the breadth of the ſands continue upon the increaſe, we muſt conclude that the reflux of the tidal water from the whole ſurface covered continues, upon the whole, if not greater, as great as formerly, and therefore will maintain as good a channel to ſea at the outfall at low water; nor does it appear from any teſtimony that, from the ſcalp to the outfall of the channel into the ſea, there is a leſs depth at high water than formerly exiſted; the complaints and appearance of a diminution of depth of the harbour are from the lower or north end of the Pool upwards towards the town. It appears therefore, that the upper part of the channel that lies contiguous to the main land is *landing up*, and that in fact the harbour is moving *towards the ſea*.

It does not appear from teſtimony that the filling up of the Pool, or its growing ſhallower, ſo that ſhips cannot now lay afloat or ſwing round in tiers as they uſed to do at low water, has been a matter very much complained of till after the imbankment of 1758; but this does not diſprove that the fundamental cauſe thereof may have exiſted long before the ill effects have become ſenſible to ſeamen, and thoſe uſing the harbour; and indeed it clearly appears to me, that the filling up of the Pool ſooner or later, is only a link in the general chain of cauſes that muſt have operated ſo as to produce this effect, whether any imbankment had been made or not.

To ſee this clearly we have nothing to do but to advert to the ſituation of the Pool, for it begins juſt below or about where the *Weſt Fleet* falls into the main channel. This Fleet received the drainage and back waters from the *Holkham* marſhes, which appear to have been anciently of much greater extent than at preſent, and conſequently the back water or reflow

reflow muſt have been very conſiderable from this great extent of ſurface, as well as that which ſtill lies unembanked, and which being joined by the great reflow of back water from the Eaſt Fleet, the Little Fleet, and the Haven Creek, with all their extenſive dependencies, muſt have formed a great and rapid ſcour of back water, eſpecially when it is adverted to, that it is confined within a narrow compaſs between the Holkham and the Wells Marram Hills or Miels; we muſt therefore expect no leſs than a very deep channel in this extent, well deſerving the name of *The Pool*. And that this confinement of the whole water both of flood and ebb, between the hills juſt mentioned, gave an additional ſcouring power to the tidal water, appears further from this, that the Pool never appeared to be of further extent northwards till this opening between the hills being cleared, the tidal water having an opportunity of eſcaping on tide of ebb over the broad ſands lying without thoſe points, its force became diſſipated, and the great and ſudden ſcour ceaſed, that cauſed this deep water even in that age when the whole ſcour was in its greateſt degree of ſtrength and perfection, and the depth and goodneſs of the harbour conſequent upon it. But whenever (as has been ſhewn) the ſcour beyond it became diminiſhed by the riſing of the marſhes above the high water of *neap tides*, the depth of the pool would begin to diminiſh, for the ſcours would then be unable to ſcoop out the ſands from ſo great a depth as before, that would be continually brought in by the N. W. winds at *Holkham Gap*, from the broad ſands lying to the north thereof, and then by the Weſt Fleet carried down into the Pool.

Nor is the Holkham Gap the only ſource from whence the ſands brought down by the Weſt Fleet might be collected; for I look upon it that the inſide, that is the ſouth ſide, of the Holkham Miel Hills, is continually melted down by winds and rains into the great area or bay drained by the Weſt Fleet, while thoſe hills are continually ſupplied with freſh ſand blown up by the force of the N. and N. W. winds upon and over them, from the broad ſands that are yearly extending more and more from thence to the northwards into the ſea; the higheſt parts of which broad ſands being frequently left at neap tides long enough to be dried by the ſun, are by the wind capable of being blown up in great quantities, ſo as to raiſe and continue thoſe hills far above the high water of any tides whatever, though compoſed of nothing more than a blown ſand from the ſea, ſomewhat united by the bent graſs that grows up through the ſame, of which there are very many examples in various parts of the kingdom.

In that age when the ſcour at the pool was in its full perfection, it is probable that it was very much deeper than it has ever been reported by any teſtimony or record now extant, and ſo long as it continued deep enough for the purpoſes of ſhipping, there would be no cauſe for complaint; and till it became too ſhallow for ſhips to ſwing at low water, its

its diminution of depth would be little regarded. There is therefore no doubt but that the Pool was growing ſhallower long before the imbankment of Holkham marſhes, as a conſiderable length of time muſt have elapſed between the period when Holkham imbanked marſhes were juſt riſing above the high water of neap tides, and their acquiring the height at which they were imbanked; and which height I judge was not materially different from the preſent.

When the ground of Holkham marſhes was become high enough for embankment, the natural ſcour ariſing therefrom was diminiſhed from what it had been, and though they had not been imbanked, would have been ſtill much leſs at this day. Yet ſo great a ſurface as 560 acres, the drainage of which plainly appears by the map to have made its way out to ſea by the Weſt Fleet, being cut off all at once in the year 1719, and 108 acres more in the year 1721, the whole of this together amounting to 668 acres, may reaſonably be preſumed to have had ſome ſenſible operation in accelerating the effects that nature in her progreſſion would afterwards have brought on, though no artificial imbankment had been made; but it by no means follows, that the effects of thoſe imbankments muſt be *immediately* perceived at the Pool. This by ſlow and imperceptible degrees muſt be ſuppoſed going on as before, and by leſs ſlow but yet imperceptible degrees might be going on after; yet this muſt be attended to, that in proportion as the ſcour of the weſt fleet was diminiſhed by the loſs of the imbanked marſhes, the power of the ſame ſcour would be diminiſhed to carry down the ſand continually into the pool, as it before uſed to do, ſo that till the great bay that ſtill continues to be drained by the weſt fleet, as it were gorged with ſand from Holkham Gap and Holkham Miels, it would not be brought down in ſo great quantities each tide as before the Holkham imbankment; and therefore as it appears that the whole progreſs of this buſineſs is very ſlow, it muſt be expected to have been a ſeries of years between the *cauſe* from the Holkham imbankment and the *effect* becoming more perceivable in the ſanding up of the pool; and in caſe this neceſſary period of years extended from the year 1720 to the year 1758, that is near 40 years, at which time the laſt imbankment was made, then thoſe would become *cotemporaneous* events, and it would be no wonder that the united effects of the Holkham imbankment, and that of the Church marſhes in the year 1719; and alſo of the Weſt marſhes of Wells in the year 1720, making in the whole 572 acres, together with the additional loſs of ſcour from the ſurface of the ſalt marſhes which yet remain unimbanked to the amount of between 15 and 16 hundred acres, the drainage of all which have their outfall through the Pool; I ſay it would be no wonder if under theſe circumſtances the united effects tending to land up the pool ſhould be charged to the account of the imbankment made in the year 1758, if it were poſſible to ſuppoſe that the imbankment made that year of 64 acres could have a ſenſible effect, for the object of this imbankment amounted to no more than $\frac{1}{34}$ part of the

the whole quantity concerned in producing it; when it remains *problematical*, whether the effect of the 572 acres taken in before, which is near nine times as much, would *alone* have been ſenſible, if the effects thereof had not been mixed with what might have ariſen from nature's ſimple progreſſion, in caſe its operation had been no ways diſturbed by that of art.

I find myſelf therefore forced by fair induction to infer, that though ſtrictly ſpeaking the effect of every thing that has an effect muſt be *ſomething*, yet that the imbankment of the ſlade marſhes in the year 1758, could not in any ſenſible degree capable of meaſure or eſtimation contribute to the landing up of the pool.

The effect thereof upon the outward part of the channel muſt be ſtill more remote; for it does not appear from any principles of art, obſervation, or practice, that when a back water, even aſſiſted by a freſh water river ever ſo large, makes its way through broad moveable ſands, it has any tendency in itſelf to make its way out to ſea in this direction more than in that. The natural tendency of water is to make its way in whatever direction it finds the *greateſt declivity*; and if that happen to be in the ſhorteſt direction, it has no natural tendency to gain a longer courſe, as that would leſſen the declivity: If therefore water is found going in a courſe that is not the ſhorteſt, we may conclude (and on examining we always find) that this longer courſe is owing to the intervention of ſome object ſo placed, that the water can have in that particular part a more ſpeedy deſcent in a direction different from that which would form the ſhorteſt line of the whole deſcent; and from cauſes of this kind a ſtream may have a courſe in every poſſible degree meandering that we frequently obſerve in nature.

If therefore the courſe of the out-fall channel to ſea at low water was in a north-weſt direction through the broad ſands, as it ſeems very well atteſted to have been in former times; and if at thoſe times the courſe of the channel correſponded with the general ſet of the tides upon the coaſt, ſo that veſſels going in or out through the out-fall channel were not driven out of their proper courſe by a ſet of the tide *croſs* the channel, as is ſaid to be the caſe at preſent; it may be imputed to ſome of thoſe lucky cauſes that operated in favour of thoſe times, as no ſtrength of back water alone could have a natural tendency to produce this effect: And if the accidental operation of contrary cauſes, as ſuppoſe winds and tides, either conſidered alone, or as acting in correſpondence with the regular progreſſion of nature already deſcribed, has brought the direction of the out channel into a ſituation leſs favourable to navigation than it uſed to be formerly, at the ſame time that it has produced a ſhorter courſe for it to ſea, than it would have if returned to its former direction; I am therefore clearly of opinion, that no increaſe of back water, even if aided by a freſh water river, if artificially brought down

down this channel, would ever cauſe it to return to its former north weſtern direction, ſo as to diſembogue itſelf, at a place conſiderably more weſt than the preſent outfall.

I do not however mean to ſay that it *cannot return*, but that if it does, it muſt be in virtue of cauſes operating in a contrary way to thoſe which have brought the mouth of the channel from the weſtward towards the eaſt, and not in virtue of any change that can be expected to be wrought ſimply by an increaſe of back water; for that would be to make a more rapid ſtream have a tendency to go a longer journey to ſea in preference to a ſhorter.

It is alledged indeed, that, from a general increaſe of the breadth of ſands upon the coaſt, it is now further from the north end of the pool to ſea than it uſed formerly to be, but this muſt be underſtood of the ſtraight line from the ſaid point to low water, without regard to the direction of the channel. For though the preſent channel ſhould be as long from the pool to the ſea, or longer than formerly; yet from the general increaſe of the breadth of the ſands, were the channel to go much further weſtward than at preſent, it would have a longer courſe to ſea at low water.

What may have been the particular cauſes that have brought the mouth of the channel more to the eaſt than formerly, does not appear material to the preſent queſtion; but to give ſatisfaction as far as I am able, I will hazard the following conjecture: It is an obſervation univerſally agreed upon, that the N. W. winds make the higheſt tides in the whole German Ocean; the N. W. winds, then, accompanied by *higher* tides will produce more agitation, and conſequently carry the ſands from the N. W. eaſtward, in a greater degree than that in which equal winds from the ſouth-eaſt accompanied by leſſer tides will bring them back; and according to the local direction of the coaſt here, they directly tend to accumulate them upon the ſhore toward the N. E. If this is a true ſolution, as I apprehended it to be, there ſeems not the leaſt likelihood that the direction of the channel ſhould ever be permanently removed to the weſt, but rather that it ſhould be carried further to the eaſtward than it now is; and what gives ſtrength to the above conjecture is, an obſervation I had the opportunity of making upon my view, viz. that the outfall channel of the harbour of Blakeney (a few miles eaſtward of Wells, and ſituated in a ſimilar manner, in regard to the courſe of its outfall channel through the broad ſands) has ſhifted alſo more to the eaſtward than it was, by above half a mile in the laſt ſeven years, as appeared from the marks I was ſhewn for its entry at that period, compared with its preſent place; notwithſtanding that Blakeney Channel has two large freſh water rivulets that make their way together through this channel to its no ſmall advantage towards keeping it open. The place alſo of the outfall at low water of the eaſt diſcharge from the ſalt water creeks called Wareham Deeps, I was ſhewn to have removed its place further eaſtward, than it was at Michaelmas laſt, by ſeveral

ſeveral hundred yards, and that chiefly within the compaſs of the preceding three weeks to my view, during which very ſtrong north weſterly winds had prevailed. Wareham Deeps lie betwixt Blakeney Outfall Channel, and that of Wells.

There is one thing more reſpecting the outfall channel of Wells Harbour that it may be proper to touch upon, and that is, the bar that is deſcribed in Beiderman's map to lie acroſs the mouth of the channel ſo as to be prejudicial to the entry of veſſels; but after what has been ſaid, be the impediment ariſing from hence greater or leſs, it cannot be imputed to the imbankment of marſhes; but to the ſport of winds and ſeas at the place, which will further appear from this circumſtance; that when I was examining this place at dead low water of a ſpring tide, viz. the 15th of March laſt, I did not obſerve there was any appearance of a bar, the courſe of the channel being right out to ſea, at N. E. by N. by the compaſs, yet in another ſeaſon it may probably return.

Hence, from the above premiſes, I muſt entirely acquit the whole of the imbankments, from having been in any degree contributory to the diſagreeable effects ariſing from the change of the outfall channel of Wells Harbour.

What I have further to ſay, will come moſt naturally under the third and laſt queſtion propoſed.

Queſtion the 3d, Whether the removal of the imbankment of the Slade Marſhes will contribute to any material amendment of Wells Harbour?

It appears clearly from what has preceded, that the progreſſional operation of nature, which originally formed the harbour of Wells and brought it to maturity, has alſo occaſioned it to grow more and more into a ſtate of decay; and will finally cloſe it up, and convert into firm ground, fit for arable purpoſes, and thoſe of paſturage, the very ſpot where ſhips have rode at anchor; and that this being the progreſſion of nature cannot be countervailed in any degree, but by the induſtry, art, and hand of man.

It is a fact well eſtabliſhed by evidence, that, previous to the erection of Freeſtone's Sluice in 1749, the upper parts of the harbour, as far down as the pool, had got landed up to that degree, that the ſhipping, which chiefly laid in the pool, were obliged to have a great part of their ladings brought and carried to and from the town by lighters. That upon the erection of Freeſtone's Sluice (which as far as appears was the very firſt attempt in this harbour to counteract the operations of nature by art this

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rude and ſimple piece of art ſucceeded ſo far as in a very great meaſure if not effectually to relieve the diſtreſs that they then laboured under; viz. that of the quays being in great meaſure inacceſſible to ſhipping; a conſtruction ſo rude, that though bearing the *name* of a *ſluice*, it would ſeem as if it had been one of the firſt attempts to obtain relief by art, before ſluices had been invented; and hence we may infer, that if this did ſo much, what might have been effected by a *real ſluice*, built upon a proper and regular conſtruction. This ſluice however was attended with a beneficial effect ſo long as it laſted; and when it went to decay, the part of the harbour affected by it reverted to its former ſtate.

In the year 1765 they again ſet about to relieve themſelves, not by building a ſluice upon a better plan, but by erecting a new one upon the ſame plan, upon freſh ground, with better, and as they expected more durable materials: And this ſluice reproduced afreſh the effect of the former, which has indeed continued to this day. But in the year 1777 it was diſcovered to be defective and liable to fail on account of the timber wherewith it was built being eaten with a ſea worm, unknown in theſe parts before, that had attacked it. On this occaſion Mr. Wooler, an ingenious engineer, very competent to the buſineſs, was called in, who very judiciouſly adviſed, not only to build a new ſluice upon a new foundation, and of more durable materials, but of a different conſtruction, ſo as to give a better effect to the iſſuing waters, as the beſt means for preventing the harbour going to decay. This ſalutary advice however appears to have been rejected by the commiſſioners of the harbour, on account of the expenſe; in lieu thereof, they adopted another expedient, which, as they thought, was liable to be attended with leſs expenſe, and quite as effectual. Having obſerved, on popular grounds, that many things had gone wrong with the harbour ſince the laſt imbankment in 1758, they ſuppoſed that they were the effects of that meaſure; and inferred that by removing the cauſe, the effects would ceaſe, and every thing come right again. It ſhall therefore now be my buſineſs fairly and fully to examine what foundation there was, or may be, for ſuch a ſuppoſition.

As the commiſſioners of the harbour I preſume did not pretend to profeſſional ſkill in *civil engineering*, they could be no otherways blameable for miſjudging in a matter dependent on that art, than that had they fully examined the queſtion upon the like popular grounds, which are alike intelligible to all men, they would have ſeen there was no juſt foundation for their expectations. For in the year 1749 the waters of the Slade Marſhes had not been interrupted in their operation, and yet this harbour was become choaked, and had got into ſo bad a ſtate, as to call aloud for immediate relief; what reaſon then had they to expect it in the year 1778, when, according to the natural progreſſion, every thing had got worſe?

In

In 1758 Freeſtone's Sluice had gone to decay, and the harbour was ſpeedily reverting to the ſtate in which it had been before the year 1749. Now had the operation of the Slade Marſh waters been obſerved to have been of any material conſequence, the imbankation of 1758 would have been oppoſed and objected to at the time, which yet does not appear; and had any bad effects appeared to have ariſen from the imbankation in the year 1768, that is ten years after the imbankment, and three years after the rebuilding of the ſluice, when an application to Parliament was neceſſary to get freſh powers to defray the expenſes incurred by that erection, &c., it would have been natural to endeavour to get ſome equivalent for the damage, or at leaſt, as ſluice-building muſt then appear to be the beſt expedient, to have got powers over the grounds in the unimbanked marſhes to enable them to erect ſuch proper additional works, as might from time to time be neceſſary; and which might have been expected upon eaſy terms, and without depending on leave being always given in caſe any damage to the harbour had been felt or apprehended from the imbankment, becauſe the more amicable terms ſubſiſted at that time between Sir John Turner and the commiſſioners, the leſs he could have oppoſed or denied ſo reaſonable a requeſt. But yet nothing of this appears, or indeed any other, till after the year 1777, when Mr. Wooler had reported that a proper ſluice was "of the utmoſt importance towards keeping the "channel of the harbour open, and clear of the ſands that are conſtantly brought in by "the tides;" and that ſuch a work would probably coſt the ſum of £2,000. Theſe I ſay are popular arguments, which as every one can equally ſee the force of them, ought to have induced the commiſſioners to ſeek relief, by purſuing means of reducing Mr. Wooler's advice to execution, rather than deliver the Slade Marſhes once more to the empire of the ſalt waters: but as a profeſſional man, I conceive it will be expected from me to give a direct proof of the efficacy of this idea; of this I ſhall therefore endeavour to acquit myſelf in the cleareſt manner poſſible.

Reſpecting that part of the laſt imbanked marſhes that lies weſt of the ancient imbankments, comprehending 16 acres, it is evidently of no more account than any other 16 acres that lie immediately upon the haven creek, and whoſe waters immediately ebb within the tide, without paſſing through the ſluice; that is, they would have no other effect in ſcouring than as making a part of 1770 acres, the water from which makes its way to ſea by the Pool; but with reſpect to the forty-ſeven acres that lie eaſtward of the ancient imbankment, and are called the Slade, or Slade Marſhes, they appear to me to have a different import.

The reaſon why the waters paſſing the ſluice have a greater effect in ſcouring than thoſe which return to ſea without paſſing the ſluice, is, becauſe by the contracted opening of the paſſage of the ſluice, the waters that lie in the creeks behind it are detained from ebbing ſo quickly as they otherwiſe would have done; that is, their numerous mouths when always open, reduced

reduced the level of the water contained therein, to nearly the ſame level as that of the water in the main channel of the harbour, being ſtopped by dams made acroſs and united by croſs paſſages into one, and the mouth of this being contracted by the work called the ſluice, a body of water is held back in theſe creeks, as reſervoirs, which not being able to eſcape ſo faſt as the tide ebbs in the main channel, it follows, that a body of water by theſe means is vended upon, and after the half ebb, which diſcharging itſelf into the harbour's creek, forms a ſcour when the depth is ſo much leſſened as to operate with power in grinding the bottom, which otherwiſe would have been ſo languid as not to have ſtirred a grain of ſand or mud, in which caſe its effect would be little or nothing. This artificial ſcour thus procured, in ſome degree imitates the effect of a freſh water river, which in theſe ſituations is very greatly beneficial, not from any virtue there is in freſh water preferable to ſalt in theſe caſes (if any thing rather leſs on account of its leſs ſpecific weight), but from its having a fall from the land, and proceeding therefrom continually it not only ſtrengthens the ebb, but running to ſea at low water when the fall being greateſt, and the ſandy bottom expoſed to its action, it continues to work at a time when it can operate to the beſt advantage; and when the ordinary current of a river is aſſiſted by extraordinary land floods and freſhes from downfalls of rain and ſnow, and this operating at low water, when, as juſt remarked, the fall is the greateſt, in ſuch caſes it is capable of producing extraordinary effects, and of keeping a harbour continually open with a channel of a given magnitude, though loaded with ſands in any poſſible degree: for a freſh water river has this peculiar advantage, that at the ſame time that it ſtrengthens the ſcouring power of the ebb, it operates moſt forcibly at low water, when there is the leaſt to obſtruct its operation; it oppoſes the tide of flood from the ſea, and thereby prevents its bringing ſo much ſand and ſilt into the harbour as otherwiſe it would.

The defect therefore of this ſluice of Wells is, that though it retains the waters ſo as to be behind the general ebb, and thereby ſtrengthens the latter part of it conſiderably; yet being at low water all ſpent, when the greateſt good might otherwiſe be obtained, it loſes that good effect which would be had from a freſh water river, or from a proper ſluice; that is, one that will retain the water wholly till a proper time of tide, and then being let go in one collected body, is capable in a ſhort ſpace of time of producing marvellous effects; and yet I ſhould not expect ſuch a ſluice either to clear the Pool to the depth it had fifty years ſince, or to carry the outfall channel to the Northweſt.

By ſluices of this kind, which are the only expedients art has found that is comparable to a river, the greateſt part of the ſea ports in Flanders and Holland are kept open, and under

under circumſtances more unfavourable than the port of Wells, many of which are built not only with great expenſe, as to the uſeful part, but with much magnificence, as relying upon the durable utility of their conſtruction. Thoſe of the Wells traders who have occaſion to viſit the port of Oſtend, ſo much reſorted to at the preſent time, will ſee a remarkable example thereof in the grand Sluice of Oſtend re-erected in the year 1755.

The Slade then conſiſting of 47 acres (or ſomewhat leſs, on account of the high grounds incloſed therewith), it appears to me might derive ſome occaſional advantage in reſpect of ſcouring, from the very circumſtance of their ſituation lying behind the ancient imbankment; inſomuch that what is alledged by ſome of the witneſſes may at ſome particular time or times be true; videlicet, that when the tide was ſpent at the town, it came down from the Slade.

It ſeems well atteſted, and from the nature of the thing (as it appeared on my view) muſt be the caſe, that the ſurface of the Slade never uſed to be overflowed, but in extreme ſpring tides, here called *rages*, and the condition of it in growing ruſhes and other vegetables peculiar to fenny freſh waters before its imbankment, ſhews this to be the general caſe; and this would naturally and neceſſarily ariſe from the very contracted channel and opening left between the N. E. bank of the ancient imbankment and the high land ſo narrow, that it does not appear, except in ſuch caſes, that there would be a ſufficiency of time at high water for the whole ſurface of the Slade, conſidered as a pond, to fill any thing near the utmoſt height of the ſea; but yet whatever water was at ſuch times brought upon it, would, upon the ſame principles as the ſluice, be left behind, and retained by the ſame narrow paſſages, ſo as to require poſſibly the whole of the ſucceeding low water entirely to vend it; but then it will follow, that by how much it was the longer in vending, it would come down the more leiſurely, and toward the latter part of it the more dribbling, in proportion as its channel to let it out grew more contracted by the ſurface of the water being lower therein: ſo that although it might at thoſe times come down in good quantity in the firſt quarter's ebb, where meeting the remains of the waters from the 16 acres of Slade Marſh, and other waters from the unimbanked marſhes, that ſtill fall into the haven creek without paſſing the ſluice, and might make a ſenſible increaſe of the current; yet as this muſt greatly fall off after the top waters were gone, and give but little aid in the latter part of the ebb, when it was moſt wanted, muſt equally appear plain and clear. But yet whatever good effect might be aſcribed to the water from the Slade, or in reality it might have, when it could operate in the manner I have pointed out, yet as it appears from equal teſtimony that thoſe rages happen but ſeldom (four or five times in a year), they could be of no material benefit, becauſe their power of ſcouring and grinding the bottom,

bottom, inaſmuch as the ſea is inceſſantly bringing in a freſh acceſſion of ſand, ſilt, and mud, muſt be in proportion to their *frequency*, ſo that if it were to be ſuppoſed (what it does not appear to me reaſonable to admit), that the effect of the Slade waters was when they happened even equal with that of the ſluice, yet the ſluice, if we put the neap tides out of the account, operating 365 good tides in a year, and thoſe but five, the benefit could only be as 70 to 1; an effect ſo ſmall, that, when mixed with many others, could not be perceived; and though in the eye of reaſon every thing that operates at all muſt have an effect, yet it clearly appears to me that the effect to be expected either by the ſhutting up or opening thoſe marſhes in the manner they were before the imbankments in 1758*, could procure no ſuch beneficial effect upon the harbour as to prevent the neceſſity of ſupporting and continuing the ſluice, or even to be of any meaſurable or eſtimable degree or value; and that this explanation of the ſmall utility to be derived or expected from the Slade marſh waters, is in reality the true one, is proved by the facts already ſtated; viz. that before the year 1749 they had proved *totally ineffectual*, and had always proved ſo ever ſince when the ſluice was out of order. I muſt therefore conclude in the ſentiment of Mr. Mylne, that whoever would find a cauſe for the alteration of the courſe of the out-channel, for the filling up of the Pool, for the landing up of the harbour, channel, or creek, and in general the decaying ſtate of the harbour of Wells, muſt ſeek ſome cauſe far more extenſive than the imbankment of the Slade marſhes in the year 1758, and the remedy from human induſtry and art in ſomething more powerful and better adapted than any of the ſluices there applied appears to have been.

London,
4th *May* 1782.

J. SMEATON.

* I ſay in the manner they were before the year 1758, that is, when there was no bank at all; becauſe if a partial breach was made in the bank, the waters iſſuing through this breach would have an effect ſimilar to the ſluice, till worn by the entering and iſſuing waters too wide to produce the effect, as was the caſe when Freeſtone's Sluice was worn too wide, it ceaſed to do its duty.

REFERENCES

REFERENCES to the Plan of Wells Harbour.

Plate 1. Fig. 2.

		A. R. P.	
1	Holkham Marſh, imbanked about the year 1719, by the late Lord Leiceſter, including creeks	560 0 0	
2	Wells Weſt Marſh, imbanked 1719, by Sir Charles Turner, including creeks	108 2 12	
			668 2 12
3	Weſt Salt Marſh	588 2 0	
4	Lodge Marſh	266 2 35	
5	North, or Out Salt Marſh	717 2 25	
	Channels and creeks	146 1 12	
			1,719 0 32
6	Eaſt, or Church Marſh, excluſive of the ancient creeks	106 3 2	
	Creeks in ditto	4 0 0	
			110 3 2
7	Warham Slade, excluſive of the ancient channel and creeks	59 1 36	
	The channel and creeks in ditto	7 0 32	
			66 2 28
		Acres	2,565 0 34

A A The preſent entrance into the harbour.
B The courſe of the Old Channel by the Scolph.
C C The weſt ſide of the antient entrance into the harbour.
D Friſton's Jurties.
E E The arrows ſhewing the ſet of tide over the ſands on this coaſt, for the laſt three hours of flood and the firſt three hours of ebb.
F The place of the ſecond buoy at the turn by Broom's wreck.
G The preſent navigable channel at the Scolph, ſince the imbankment made by Sir John Turner.
H The preſent Pool.
I The Quay.
K The bank made by Sir John Turner in 1758.
L The place to which the water uſed to flow before the imbankment made at K.
M N The places where the waters from the weſt marſhes empty themſelves into the main channel
P P The line from which it is ſuppoſed the water has drained towards Wells Harbour.

ABERDEEN HARBOUR.

The REPORT of JOHN SMEATON, Engineer, upon the Harbour of the City of Aberdeen.

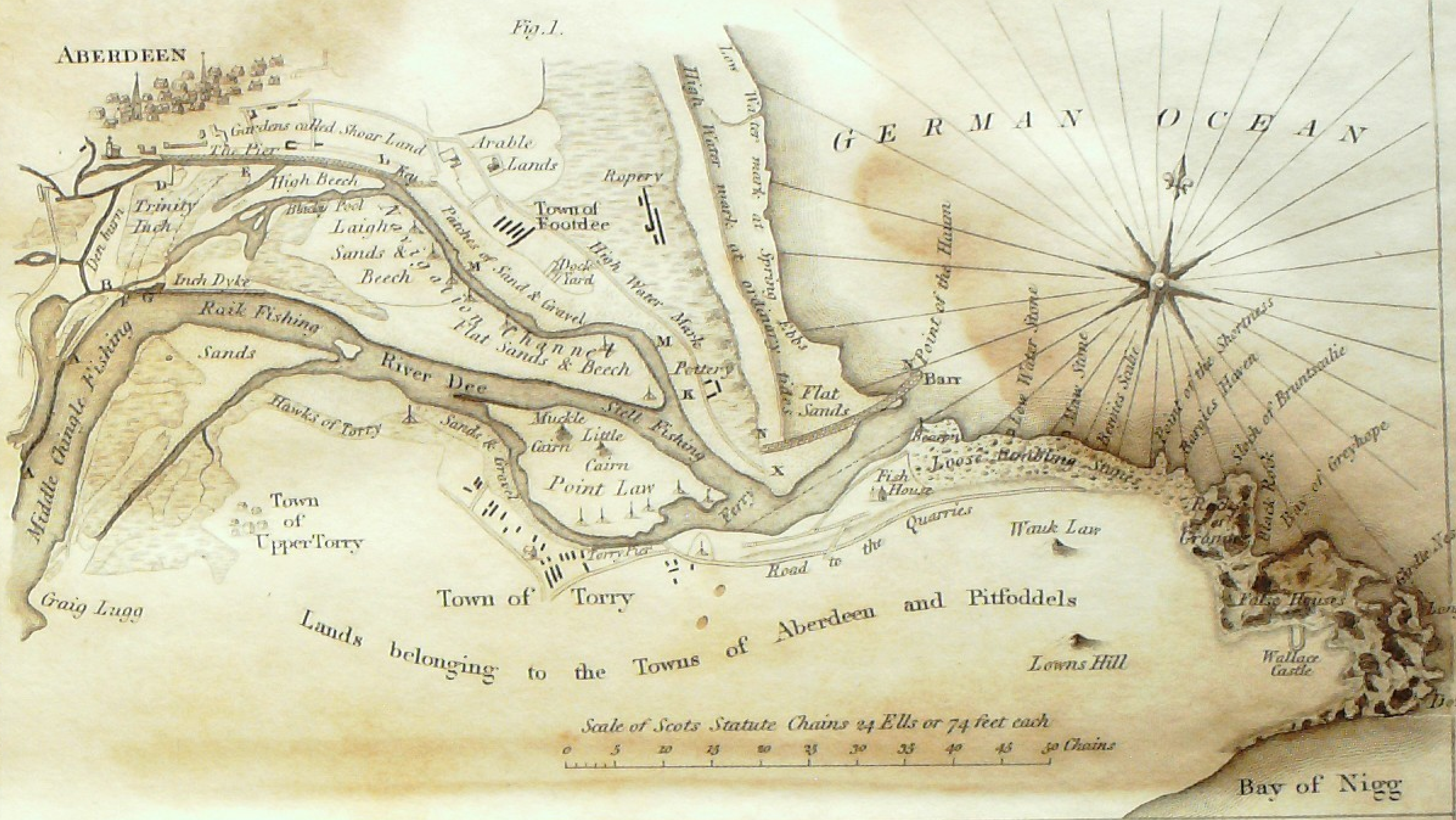
(See a Plan, Fig. 1. Plate 2.)

THE principal complaint attending this harbour is the difficulty of entry, occaſioned by a barr a little without the harbour's mouth, and a ſhifting bed of ſand, gravel, and ſhingle on the north ſide of the entry, which, by the action of the ſeas, when the wind is in the north eaſterly quarter, drives into the main channel, choaking it up in different degrees, according to the violence of the ſea, the ſtate of the tides, and of the land ſpeats, floods, or freſhes in the river Dee, which here falls into the ſea.

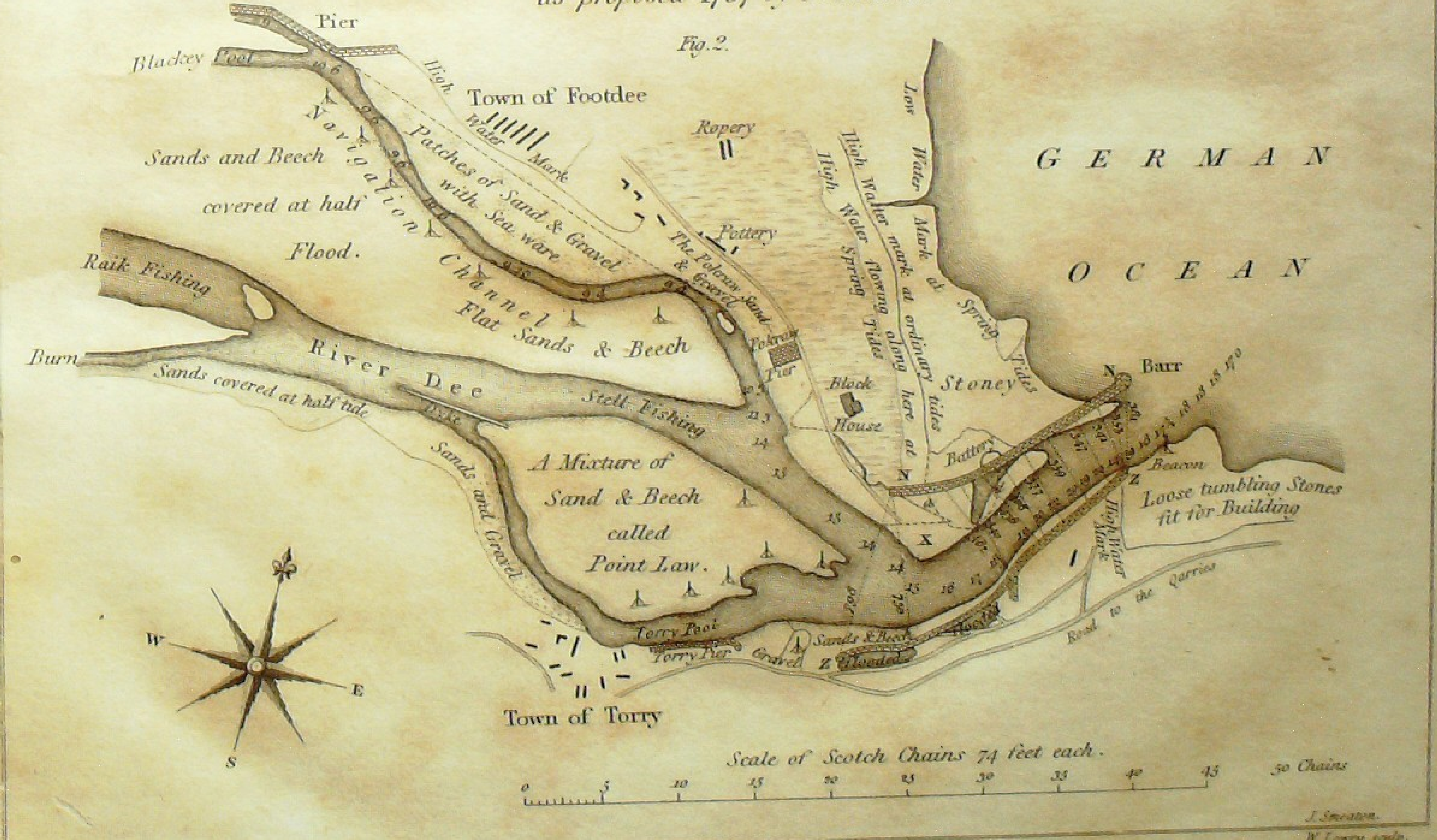
When I was there, which was in the month of Auguſt 1769, the entry was then ſaid to be in a good ſtate; and on ſounding it upon the 7th of that month, which was the 6th day after the new moon, (and conſequently the tides in a mean ſtate between ſpring and neap), I found full four feet of water upon the bar at low water, and at high water the ſame day full fourteen feet; but it is ſaid that the ordinary ſpring tides make but much about the ſame depth upon the bar at high water, and that at low water the barr is left with only the run of the river over it. The neap tides it is ſaid uſually make ten feet water upon the bar, but this is to be underſtood (I ſuppoſe) at ſuch times as the entry is in a good ſtate. On ſounding at low water, I found the body of the bar to be compoſed of looſe ſtones of different ſizes, and the whole intermixed and compacted together with gravel, over which was a layer of ſand from ſix inches to a foot in thickneſs, which after great land freſhes is ſaid to be quite ſwept away, and the ſtones and gravel left bare, which is its beſt ſtate. The bar is but of ſhort extent, and both within and without we quickly get more water by three feet. Without the bar the water gradually deepens and forms a very good road for ſhips to ride at low water, and is naturally protected from all winds except the north eaſterly and eaſterly, which blow right into the harbour's mouth, ſo that were there a little more depth of water over the bar, and this *certain*, this harbour would be capable of affording very good protection to merchant ſhips trading into theſe ſeas.

The

Plan of the HARBOUR of ABERDEEN as it was in 1769.



Plan of the HARBOUR with its Alterations, *as proposed 1787 by J. Smeaton.*



J. Farey Jun. del.
W. Lowry sculp.

Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

The cauſe of the obſtruction of the harbour's mouth appears to me to be this : The whole coaſt, which ſtretches away northerly, is apparently for miles a flat and ſandy ſhore, and I ſuppoſe from the harbour of Aberdeen till it meets with the point of Buchaneſs, (which is at the diſtance of ſeven leagues), continues of the ſame kind ; conſequently the wind at N. E. acting obliquely upon it, brings the ſands and gravel intermixed coaſtwiſe towards the ſouth ; and as the coaſt from the ſouth ſide of the entry of this harbour ſtretches away nearly eaſt for about three quarters of a mile, thoſe ſands would naturally be depoſited in the angle of the coaſt formed at the harbour's mouth, did not the land waters of the river Dee, in finding a paſſage to ſea, force themſelves a vent, which they maintain more or leſs clear according as the circumſtance of winds, tides, and freſhes, balance one againſt another. A hard gale of wind at N. E. as already mentioned, gradually brings the ſands and gravel coaſtwiſe ſouthward, and puts in agitation that already lodged in the bank on the north ſide of the harbour's mouth, at the ſame time forcing it into the entry, and if at that time it happens to be ſpring tides and little freſh water in the river, a ſtrong tide of flood being the conſequence, greatly co-operates with the wind and ſeas in carrying a large quantity of ſand and gravel into the channel of the river ; and the freſh water in the river being ſuppoſed then very ſhort, the reflux will be very languid, and being counteracted by the impetus of the ſea, it cannot return ; and a continuance of weather and circumſtances of this kind, will put the mouth of the harbour into the worſt ſtate, in which it muſt neceſſarily remain till by a contrary diſpoſition of circumſtances a contrary effect is produced. On the other hand, a continuance of great land floods, either at ſpring or neap tides, accompanied either with off ſhore winds or moderate ones at N. E. gives the greateſt advantage in ſcouring away the ſands and gravel from about the harbour's mouth, carrying it out into the road, from whence by degrees it gets round the point of *Girdleneſs* ; and if towards the cloſe of the work there happen along with a ſtrong land freſh, low ſpring ebbs, which give the current the greateſt fall to ſea, and at the ſame time run bare over the bar with a moderate wind at N. E. which will give the ſand ſome agitation without much impetus ; under theſe circumſtances, the ſtony body of the bar will be cleared of ſand, and the harbour's mouth be put in its beſt ſtate, and ſo will remain till the contrary cauſes produce as before the contrary effects : and in this ſtate of fluctuation muſt the entry of the harbour of Aberdeen ever remain, till ſomething is done to counteract the effects of that arrangement of circumſtances whoſe natural tendency is to do harm.

The only means by which I can ſee that this is likely to be effected, is the erection of a north pier, as ſhewn at N. N. in the plan, which will directly tend to the cure of the evil

evil complained of; for it will not only keep the land freshes more confined in a body till they come into deeper water, but what is of more consequence, will in a great measure prevent the sand and gravel from being driven in. It will not indeed stop the continual driving of the matter coastwise from the north, but after the back or outside of the pier is filled up with sand, &c. to a certain degree, it will then go round the pier head, and by the superior action of middling freshes and spring ebbs will be kept in deeper water, and so get round the point of Girdleness, without getting into the harbour's mouth, or at least not in such a degree as to obstruct the navigation. By this means, as the bar will not only be kept clean down to the stone bed, but by lifting the larger sort of stones by art, the remaining gravel will wash out into deeper water, so as to make (as may reasonably be expected) full two feet more water than there now is in its best state.

I can see no objection to the putting of this work into immediate execution, save the expense of it. To reduce this as much possible, I have endeavoured to propose such a construction, as, consistently with that solidity and permanency which a work of this kind ought to have, consists of the smallest quantity of materials and workmanship that I can think sufficient; and as the materials which nature furnishes here are of the best kind for the purpose, and are found near the place, I am in hopes that they will be raised and put together considerably cheaper than I have supposed in my estimate, which for that reason I desire may be considered in no other light than a form or blank, comprehending species and quantities: for as my stay at Aberdeen was necessarily short, the requisite examinations immediately relating to the harbour prevented my entering into those enquiries, which tended only to acquaint me with the price and value of labour and materials. I therefore can only fill up the blanks by comparison with what has been done at other places less advantageously situated with respect to materials, and perhaps that of labour also: in order therefore to come at a real estimate suited to the place, I must beg leave to refer myself to the enquiries of the magistrates concerning prices, or to a committee deputed by them for that purpose; and which, from their particular knowledge of the country and of the workmen, will I apprehend be done to more advantage than I could have done myself, without a longer stay than my other avocations could possibly admit of.

One thing, however, I must beg leave to suggest, that though what I now offer is as I apprehend the complete thing, which I expect to answer in the best manner, yet I am of opinion that it will be found if the pier be not carried out so far by 200 feet, that it will in a great measure relieve the present annoyances, nay, that it will be of singular service if carried out but just beyond the present pier, on the south side of the entry, in which case it will be shortened by 350 feet. In the former case the expense will be reduced according

cording to my estimate by £2,028, and in the latter by £3,549; and as the work ought to be begun from Sandness Point, where it is easiest and cheapest to be done, the workmen will gradually learn the way of doing it to the best advantage, and will probably be able to contract for the more expensive part, upon better terms than would seem to them feasible at the beginning; and as the work advances, the benefit and effect will be seen, so that it needs not to be carried further than by experience shall be proved necessary.

I come now to the improvements that may be made in the internal part of the harbour. Here I cannot but lament that the course of the river is distracted by so many channels, and covers so great a breadth of ground at high water, which want of confinement is not only detrimental to the procuring of a deep channel at the harbour's mouth, but within the harbour also, and it is particularly disadvantageous that the main current of the river does not sweep the face of the town's key at L: this I should without any hesitation advise to be done by art, were it not for the fishing properties upon the main channel; but, as I must suppose them irrevocably established, it remains to point out what is the best that can now be done, the fishings remaining as they are. I observe that within the Point of Sandness there is nearly the same water as over the bar, till the main river channel and navigation channel divide, which part of the river is marked in the plan as the *Stell Fishing*. In this part of the river, which is land-locked from all winds, vessels that will bear the ground, and whose draft of water is such as not to admit of their going further up, may safely deliver their cargoes, or shelter themselves when they come in by way of refuge; but after the aforesaid division the navigation channel M M becomes immediately shallow, carrying however ten feet water till we arrive above the new pier called Pockraw Pier at K; when opposite the ropery and dock-yard it falls a little shallower to nine feet four inches, from thence it holds nine and a half and ten feet, till meeting with the town's pier or key E L, it again breaks into two channels viz. that which stretches along the face of the pier, and that which is called the Blacky Pool. The navigation channel by the pier side, from the aforesaid division, falls off at first to nine, then to eight, and gradually to seven feet water.

The desirable improvement pointed out to me, and which seems of great consequence to the trade of the city, is to deepen the navigation channel quite away from the new pier to the west end of the Town's Pier or Key.

I observed when there, that little or none of the current water of the river Dee, in its common state at low water, goes down either the channel by the face of the pier, or the Blacky Pool, all the outlets from the main stream that might be likely to take this course, being barricaded by stone dykes, raised from two to three feet, or thereabouts, above the ordinary

ordinary surface of the Dee's water, so that nothing worth notice, till the water is swelled above those dykes, can go down the above-mentioned channel, save the water of two small burns which empty themselves by the navigation channel. With these helps, however, but principally by the current that passes through it and the *Blackey Pool* during such speats as overflow the aforesaid dykes, the navigation channel is kept open.

It has been proposed to bank in the low grounds lying west of the old pier marked D, so as to pen in the spring tides, and at that place to erect a sluice to be drawn at low water, and by making an artificial scour to deepen the aforesaid navigation channel.

Great effects are capable of being produced by the operation and judicious management of sluices in situations adapted thereto; that is, where there is a great command of fresh water, or a considerable declivity in the part to be scoured. Here as the water to be pent in is not considerable in itself, must be in a great measure tide water, which, as the imbankation would in a great measure prevent all currency through it, would be subject to silt up the reservoir, and the length according to the navigation channel nearly a mile upon four feet only of descent at low water, I fear, these circumstances considered, the effect would not be found answerable to expectation. On the other hand, the imbankation preventing the speats which overflow the dykes from getting in at the head of the navigation channel, the principal natural agent would be prevented from operating, and which I should be sorry to lose. Were the long dyke, marked A A in the plan, broken down and removed, I make no doubt but that in the course of a few years the main stream of the river Dee would make its passage by way of the Denburn into the navigation channel, D E L M K, and by degrees of itself produce the effect desired, and with a little help would do it in a very few years. I state this not upon any supposition that the dyke is likely to be removed, but to shew more strongly the use of such natural advantages as still remain. I do not suppose, however, that any use that can be made of the remaining advantages will of themselves greatly deepen the navigation channel; but this I suppose, that after it is made deeper by art, those natural advantages may be so applied as to keep it equally clean at a greater depth, as they now do at a lesser.

The whole channel from the new pier at K to the town's pier extending from D to L, does not need a great deal to make it good ten feet water, and it may be very successfully deepened by a ballast lighter, constructed like those used upon the river Thames for getting ballast for the ships. Those lighters work by direction of the Trinity House upon such shoals as are most injurious to the navigation of that river, and all the ships of that port are obliged to take their ballast from them at a certain price. Perhaps much ballast

ballast is not taken out from the port of Aberdeen, but such as is, may be supplied by this lighter in aid, as far as it goes, of the expense of raising it.

The channel for the whole length of the pier or key I would propose to be deepened by the mattock and spade at low water, which deepening being done two feet at a mean, will give ten feet water to the middle of the pier where now there is but seven feet six inches; and this being done to a breadth of sixty feet will admit of two vessels to lie abreast with sufficient passage. This work will be attended with no extraordinary expense in proportion to the utility thereof, and will endure for several years before the state of the channel will return to what it now is; yet it would undoubtedly return by degrees to the same state, unless some counter-balance be applied to prevent it: what I would therefore recommend for this purpose is as follows:—

To erect a strong stone dyke beginning at the head of the Inch Dyke at F, in the direction of the dotted line F E to the beacon E upon the Trinity Inch; or if it should anyways happen to interfere with the Raik Fishing, to carry it from a lower part of the Inch Dyke to the said beacon, according to the direction of the dotted line G E: this dyke to be made so as to rise above and keep in the water of the high land floods at half ebb of the tide, and to be made firm, so that the current may in great land floods at high water go over it, without hurting it; by this means the greatest part of the water that in time of speats flows over the present dykes, and makes its way partly by the Blacky Pool, partly over the surface of the higher lands, and partly by the navigation channel along the face of the pier, will all be constrained to go through the channel alongside the pier, and therefore will be as adequate to keep clear that channel at ten feet depth, as the present channel joined to Blacky Pool is to keep it at that mean depth from their junction to the junction of the main river at the Stell Fishing: and as these operations are plain and simple, and will be attended with no considerable expense, I earnestly recommend their execution.

It is also very practicable in like manner to join the old pier D by a dyke across the Trinity Inch to the elbow of the river, a little above the Inch Dyke B; and also by putting sluices upon the opening between the north end of the old pier D and the west end of the town's pier or key to pin in the tides, in order to make artificial scours: but as the building and maintenance of sluices would be expensive, if made so capacious as not to be an impediment to the current and action of the land flood waters, as above mentioned, and would have no considerable effect, unless the water was pent up higher than the present fishing dykes, (the banks whereof if so would in a great measure prevent the flood waters going that way); it therefore appears that since sluices of any kind are likely

likely to prevent more good than they will do, that the plain, natural, and ſimple method firſt deſcribed, of making a dyke according to the ſingle dotted line E F as firſt mentioned, is the moſt eligible to be put in execution. Upon the whole, I am of opinion the methods pointed out to be purſued, without and within, will remedy the complaints the harbour is ſubject to, as far as is above ſpecified, and poſſibly in a ſtill greater degree.

Auſthorpe,
19th *February* 1770.

J. SMEATON.

ESTIMATE for the North Pier of Aberdeen, &c.

	Cube feet of ſolid rough blocks.	£	s.	d.
This pier N N being begun at the high ground of a point called Sandneſs Point, marked X, not ſubject to be overflowed with the tide, may be carried out for 400 feet gradually increaſing, being 20 feet baſe, 12 feet top, and 12 feet high, will contain as follows, videlicet,				
In the baſe for 2 feet high - - - -	40			
In the ſide at 3 feet mean thickneſs and 10 high - -	60			
In the platform at top - - - - - -	5			
Solid rough blocks per foot running at 4*d*., £1. 15*s*; and for 400 feet length - - -	105	700	0	0
To 87 cube feet of chiefly large and ſome ſmall rough ſtones for filling, which reckoning 13 cube feet and a half to the ton (that is, 2 ton to the cube yard), makes 6 tons and a half per foot running, which at 2*s*. 6*d*. per ton laid in place amounts to 16*s*. 3*d*. per foot running, and for 400 feet to -		325	0	0
The parapet being at a medium 4 feet 6 inches baſe, 3 feet top, and 4 feet high, will contain 15 cube feet per foot running, and reckoning as before 4*d*. per foot for block ſtone, 2*s*. 6*d*. per ton for walling and filling ſtones, 2*d*. per foot ſuperficial over all, for work in facing, and 2*s*. 2*d*. per cube yard for mortar and extra work in walling the parapets, will come to 10*s*. per yard, cube meaſure, and therefore for 15 feet to 5*s*. 6*d*. per foot running, and for 400 feet to -		110	0	0
The 1ſt ſtretch of 400 feet of the pier - - -		£ 1,135	0	0

The

	rough blocks.	£	s.	d.
The 2d ſtretch being carried out 400 feet farther, being a mean 28 feet baſe, 14 feet 6 inches at top, and 20 feet high, will contain as follows:				
In the baſe for 3 feet high - -	60			
In the ſides 17 feet high and mean thickneſs 3 feet and a half - - -	119			
In the platform at top - -	7			
Solid rough blocks per feet running -	186 at 4*d*., £3. 2*s*.			
To 400 feet in length at £3. 2*s*. per foot running - -		1,240	0	0
To 117 tons of large rough ſtones for filling, at 2*s*. 6*d*. per ton, comes to £2. 4*s*. 3*d*. per foot running, and for 400 feet to - -		885	0	0
The parapet will contain a cube yard per foot running, which for 400 feet at 10*s*. comes to - - - - -		200	0	0
The 2d ſtretch of 400 feet of the pier - - -		£ 2,325	0	0

		£	s.	d.
The 3d ſtretch of the pier being carried out 546 feet beyond the former, and being at a mean 36 feet baſe, 24 feet top, and 24 feet high, will contain as follows:				
The baſe of blocks 4 feet high - -	114			
The ſides at a medium 4 feet and a half thick each	180			
The platform at top - -	10			
Rough blocks per feet running -	334 at 4*d*., £5. 11*s*. 4*d*.			
This for 546 feet in length comes to - - -		3,039	8	0
To 28-6 tons of large rough ſtones for filling, at 2*s*. 6*d*. per ton, comes to £3. 11*s*. 6*d*. per foot running, and for 546 feet to - -		1,951	19	0
The parapet will contain 2 cube yards per foot running at £1. per foot, and for 546 feet - - - - -		546	0	0
The 3d ſtretch of the pier 546 feet - - -		£ 5,537	7	0

		£	s.	d.
The pier head to be 60 feet diameter at baſe, 48 feet top, and 24 feet high, will contain as follows:				
The baſe of blocks 4 feet high - -	11,316			
The outſide at 4 feet and a half mean thickneſs -	16,920			
The platform - - -	707			
Rough blocks in the pier head - -	28,943 at 4*d*.	482	7	8
To 1,940 tons of rough ſtones for filling at 2*s*. 6*d*. - -		242	10	0
To 54 feet of parapet (being the length that the head is ſuppoſed to add to the 3d ſtretch, making it in the whole 600 feet) at £1. per foot - -		54	0	0
The pier head making 54 feet running - - -		£ 778	17	8

ABSTRACT

ABSTRACT.

			£	s.	d.
The 1ſt ſtretch containing	400	feet running	1,135	0	0
The 2d ditto	400		2,325	0	0
The 3d ditto	546		5,537	7	0
The pier head	54		748	17	6
Whole length	1,400	Total of the pier	9,776	4	6
The taking up the bar ſo as to make two feet water more than at preſent when clear, with incidental charges, may be ſuppoſed			223	15	6
		Total for the pier	£10,000	0	0

J. SMEATON.

Auſthorpe,
19th *February* 1770.

ESTIMATE for the Interior Works propoſed for the Harbour of Aberdeen.

	£	s.	d.
The conſtruction of a ſtone dyke in the direction F E, ſpecified in the report and plans, being ſuppoſed at a mean 12 feet baſe, 6 feet high, and made rounding at top, will take about $3\frac{6}{10}$ tons of rough ſtones per foot running at 2*s.* 6*d.* per ton, and being in length about 1110 feet, will come to	499	10	0
To clearing the channel from the new pier K to the town's pier L D, in length about 30 chains or 2220 feet, and being ſuppoſed to be deepened at a medium one foot upon 60 feet wide, will contain 4933 cube yards, which I ſuppoſe may be done by hand at low water for 6*d.* per yard, will amount to	123	6	6
To deepening the channel by the ſide of the town's pier L D, at a medium two feet upon 60 feet wide, for 1700 feet in length, will contain 7555 cube yards, which at 6*d.* will come to	188	17	6
The interior works	£ 811	14	0

J. SMEATON.

Auſthorpe,
19th *February* 1770.

To

To the Magiſtrates of the City of Aberdeen.

The REPORT of JOHN SMEATON, Engineer, upon the *In-run* of the Seas into the Harbour of Aberdeen in eaſterly winds.

(See the Plan, Fig. 2. Plate 2.)

IN conſequence of the memorial from the magiſtrates of Aberdeen, dated the 9th of April laſt, which I received in London from the hands of Mr. Profeſſor Copland, and of your further requeſt ſignified to me by Meſſrs. Carnegie and Black of Montroſe, I took the opportunity of viſiting your harbour, and made my obſervations upon the place, 1ſt, 2d, and 3d of October laſt, at which time the wind happening to be eaſterly (though not very freſh) afforded me an opportunity of particularly viewing and conſidering the mode of the action of the ſeas from this quarter, and had the pleaſure to find that the deepening of the the entry into the harbour, and removal of the bar, that was the principal annoyance complained of when I viewed the harbour in the year 1769, has been effectually removed and cleanſed, and ſo kept continually in that improved ſtate by means of the north pier N N, which has been erected conformable to my report of the 19th February 1770. But though the main object has been anſwered, and the harbour and reſort thereto very greatly improved, yet the very means by which this improvement has been effected have produced a cauſe of complaint of a very different kind, which at the time I apprehend to have been altogether unforeſeen, and that is from the increaſe of depth and freedom of paſſage, the ſwell of the ſea at high water meeting with nothing to controul it, makes its way through the clear paſſage between the two piers, and meeting nothing within the great natural baſon or bay that forms the harbour to break or diſperſe the ſeas ſo brought in; according to the nature of waves when paſſing through a narrow into an expanded ſpace, they turn round along the ſhore and ſpend their fury upon the neareſt objects in the greater degree, and in proportion upon thoſe more diſtant.

While the Old Sandneſs Point remained, which had been formed in former times before the north pier was built, and which extended more than half way acroſs the ſpace walled off by the new pier (as appears by the original Plan at X. Fig. 1.) this point of ſhoal water while it ſubſiſted was capable of taking up and breaking the heavy ſeas in rolling over it, and thereby in a great degree diſperſing them; but in proportion as the bar was removed and the entry deepened, the ſeas falling more heavy upon this point, have gradually diſperſed and removed it, and in conſequence now paſs into the harbour without controul, as has been fully and clearly ſet forth in your memorial above referred to.

The

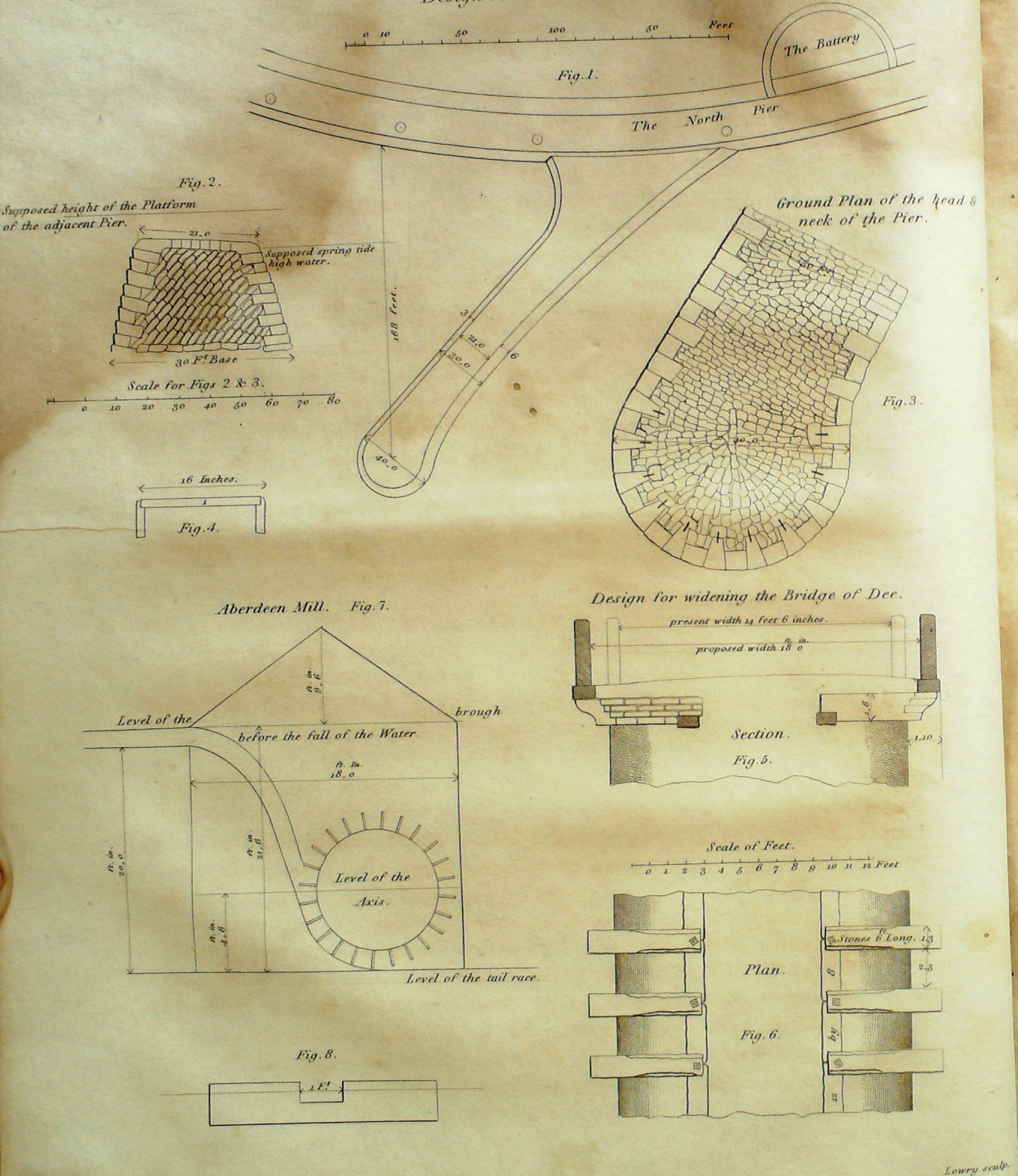
The cause of the present in-run in consequence of these alterations, being clearly owing in a great measure to the loss of the Sandness Point, it further appears that, if restored, it would be inadequate to the dispersion of the seas that now enter, owing to a greater depth at the mouth. The remedy therefore is clearly pointed out to be a construction that shall not only have the effect that it had in its original state, but one so much greater as may be in proportion to the greater weight of the seas, which from the causes stated are now liable to fall upon it.

The cause and the mode of cure being both perfectly clear, there can be no difficulty in judging that something should be done at the Sandness Point in order to its restoration; but in what particular mode and degree, as also that it may be done in the most œconomical as well as effectual way, have been to me matters of much reflection and study.

The first thing that presents itself is, to begin from the side of the pier near about where the Old Sandness Point was, and to deposit a body of rough stones projecting gradually forwards towards the middle of the open space, rising towards the pier and sloping towards the low water; and as this work will naturally be done in progression, it may be gradually carried on till it is found to produce the desired effect; and this is doubtless the clearest and easiest way of doing the business, and no more needs to be done than what is sufficient; so that in effect the *New Sandness Point* will now, instead of sand and gravel, be composed of a body of rough granite. This mode in its commencement would appear to be the most œconomical, but it is very probable that before it is ended it will require so great an area to be covered, as to contain so considerable a quantity of stone, that the same tonnage of stone being put into a regular shape would form a regular catch pier. The stones composing such a mound or bulwark must not in general be of a small size, because if the seas breaking upon them remove them and wash them into the navigable channel, they will produce an obstruction of a third kind; and if formed of large stones, I apprehend that as the quarrying and carriage of such stones will so far exceed the cost of putting them in shape when brought to the place, that they may just as well be made to form a regular piece of work. I have, however, no doubt but that the mound now proposed would fully answer the end; and if the magistrates are inclined to adopt the mode of construction, the outline of it, describing the spread that I apprehend it may be needed to have when completed, is very well described by the chain of dots that I left upon the plan that had been presented to me along with the said memorial, (these are seen in Fig. 2. at a a). In regard to any further directions they seem unnecessary, as the work is to prove itself, the sea being to break over it,

it

Design for a Catch Pier at Aberdeen.



J. Farey Jun. del.

Published as the Act directs by Longman, Hurst, Rees, Orme & Brown, Paternoster Row.

Lowry sculp.

it is only neceſſary to keep it conſtantly higher towards the pier, and ſloping towards its baſe on all ſides, as has been already mentioned, and was the caſe of the natural point.

I herewith ſend a general Plan, (Plate 3.) ſhewing the ſhape, ſituation, magnitude, and projection of a catch pier in reſpect to the preſent works, and which if carried out to the extent deſcribed, I have no doubt will have the effect of quieting the harbour; and as it will leave a clear breadth of full 300 feet for the navigable channel, I apprehend there can be no objection to its projecting the full extent of 180 feet from the ſide of the preſent north pier, if ſo required; but as it is not improbable, and indeed what I rather expect, that half of this projection may be found ſufficient, when other things are done that I pointed out when upon the place, and ſhall further enlarge upon, I would firſt propoſe to carry it out to the length of 90 feet, building up the head with a ſquare return, in the manner that was done on quitting the work of the north pier at the concluſion of each ſeaſon; and this being done, the effect of one winter will ſhew what more will be neceſſary, and in conſequence the head as deſigned may be immediately joined upon it, or it may be carried out to the full length, or to ſuch extent as may then be judged requiſite.

As this catch pier, ſo far as I can ſee, is not likely to be of uſe except as a break water, I do not mean to build it ſo high as the other, but to about ſpring tide mark; the ſeas being ſuffered to break over it at high water, which will in fact have more effect towards their total diſperſion, than that of ſolely diverting their courſe; for till they are broken and deſtroyed they will always recoil and produce the effect ſomewhere.

As I find by experience that there is nothing that ſo much tends to quaſh and diſperſe a wave when it is raiſed, as its breaking upon a ſloping beach; on this account the continuance of the ſouth pier Z Z (Plate 2. Fig. 2.) ſo far to the weſtward, (which ſeems to have no other effect than as a wall to wharf up the ſloping ſhore that lies oppoſite to Sandneſs Point), has in reality a very bad effect in the preſent ſtate of things, in keeping the ſeas from ſpending and breaking as they would otherwiſe be inclined to do upon the *naturally* ſloped ſhore at that place, as the flooded pools lying here behind the pier do teſtify. For what reaſon this wharfing has been carried ſo far weſt, it is not now eaſy for me to conjecture; but doubtleſs the ill effect of it would not ſo clearly appear before the erection of the north pier, as the north ſide was then a ſloping beach entirely. But for whatever reaſon it was done, the removal of it now is altogether neceſſary, for the ſhape and tendency of the catch pier now propoſed, being to throw the ſeas more effectually over to the ſouth ſide, unleſs there is a ſloping beach for them to break upon, they will be

be again reflected back from that ſide towards the north, and undoubtedly produce diſagreeable effects in ſome part of the harbour. I therefore propoſe, from the place ſpecified in the plan, where the weſt end of the ſouth pier is propoſed to be terminated, to remove the preſent wall entirely, making it a ſloping beach quite away to Torry Pier; and to mend the ſlope artificially where wanted: the ſtones will go in aid of the work to be carried on upon the north ſide. Fig. 1. of Plate 3. is an enlarged plan of the catch pier as now propoſed, accompanied with a ſection, Fig. 2. and a plan, Fig. 3. of the ground courſe of the pier head, the two laſt to a ſtill larger ſcale, and which, with the following explanation thereon, I apprehend will be ſufficient for the guidance of the artificers.

There is not propoſed to be any *work* upon the ſtones of the outſide, further than ſplitting at the quarries; and as in the ſplitting of granite they can as eaſily be cut into wedge-like pieces, as made of parallel ſhapes, I have ſhewn a method by which the ſtones compoſing the circular end of the pier can be retained in their places, as effectually or even more ſo, than where the pier goes out near upon a ſtraight line: for by making every other ſtone a long ſtone or *header* and more wedge-wiſe than the tendency towards the centre, the ſtones lying betwixt them may be retained in the manner of a dove-tail, and the header ſtones themſelves being anchored at their tails, that is at their inward or ſmaller ends, to an anchor or croſs ſtone by means of an iron cramp to each, the whole will be held compactly together. Theſe wedge ſtones may be of different ſizes, as they will cut to the moſt advantage in the quarry, as well as the intermediate ſtones; all that is required, is, that they decently fit each other.

The wedge-like header ſtones, employed to make the turn of the head, and hold in the intermediate ſtones between them, are to be tied to the anchor ſtones (ſee Fig. 4.) at their tails by iron cramps of one inch ſquare, turned down and rounded at each end to go into jumper holes, to be fixed therein if neceſſary, with wood wedges without lead, as the weight of the courſes above them, bonded in the ſame way, will be ſufficient to keep them from ſtarting.

I have fully attended to the contents of Mr. Carnegie's letter of the 24th ult. which only ſhew that ſomething effectual muſt be done, even to preſerve the internal works of the harbour; but when what is propoſed is put in complete execution, I expect the *tongue*, and all its complaints, will vaniſh of courſe by degrees.

Auſthorpe,
22d *March* 1788.

J. SMEATON.

ABERDEEN BRIDGE AND MILLS.

(See Plate 3. Fig. 5. and 6.)

The REPORT of John Smeaton, Engineer, concerning the Improvement of the Bridge of Dee, near the City of Aberdeen, and of the Common Milns of the ſaid City.

THE Bridge of Dee appears to be well built, and of very good materials, and the current of the river ſeems to ſet fairly through the arches, ſo that it promiſes a duration for many years. Like moſt bridges formerly built, it is too narrow, being but 14½ feet wide within the parapets, which is too little for carriages to paſs with that eaſe, freedom and ſafety which are deſirable. It is found by experience that 18 feet clear width admits of this convenience, and as this may be procured without deranging any of the more ſolid parts of the bridge, it ſeems a deſirable improvement.

As the country affords an abundance of excellent granite, which, with little work upon it, is capable of being ſplit into ſquare blocks or pillars, I propoſe to widen the bridge by laying out corbells of granite of one foot ten inches projection, and removing the parapets one foot nine inches further out on each ſide on the corbells; the bridge will then be full 18 feet in the clear. The particular method of conſtruction will be better underſtood by the deſign than by many words. Upon which I have only to obſerve, that to prevent the leaſt apprehenſion of the weight of the parapets overſetting the interior weight, I propoſe that the ſpaces between the corbell ſtones be walled ſolid, and upon the ribband ſtones which connect the tails of the corbells; ſo that of maſonry and earth there will be more than double the counterpoiſe. The corbells are each to have a bolt to hold them down firm upon the ribband ſtones; theſe are ſeen in the plan, Fig. 6; they muſt have T heads in order more effectually to engage the ribband ſtones; four inches in the T will be ſufficient.

Having carefully conſidered the ſituation of the Town's Mills, I am of opinion that of the two mills within the city, now appropriated to the grinding of malt, if the machinery were made new, one of the mills may be made to do the buſineſs that is now done by both. This being the caſe, there will be one of the mills within the city that may be applied

plied to the grinding of corn, that is, to the ſhelling of oats and grinding of oats and barley. I apprehend the malt mill may be altered for about £80. and the other to a corn mill for about £150.

On conſidering the ſituation of the Juſtice Mill, I apprehend it will be beſt to be fitted up for the purpoſe of a wheat mill, for which it has been deſigned. I judge, that when the full advantage of the ſituation is taken, and the machinery properly adapted, the mill may be made to grind and dreſs full four Wincheſter buſhels of wheat per hour, which, when there is water in winter and wet ſeaſons, may be continued for the whole 24 hours, and in dry ſeaſons ſuch as it was when I was there, about 12 hours in 24; ſo that in the ſhort water ſeaſons, it will be able to grind and dreſs at the rate of 12 bowls (ſuppoſing four Wincheſter buſhels each) per day. The expenſe of erecting ſuch a mill originally would be about £500; but as I expect the mill-ſtones will do again, with the ſmall machinery, theſe, with the larger materials and the buildings, will probably ſtand inſtead of £200. ſo that to rebuild the mill and make it fit for buſineſs, will require a further outlay of £300. As I had not a ſufficiency of time upon the place to take the neceſſary meaſures, I can only gueſs at the quantity of buſineſs to be done, and the expenſe that may attend each of the mills; but in caſe the above idea appears eligible to be purſued, by receiving anſwers on the following points, I ſhall be enabled more exactly to calculate what they will do, and form a proper deſign for their rebuilding.

1ſt. A plan and elevation of each of the mill buildings as they now ſtand.

2d. The whole perpendicular fall of the water from the level trough, lander, or ſhute, before it begins to fall towards the wheel to the bottom of the race at the tail of the wheel, noting upon the elevation where the horizontal lines cut the elevations of the reſpective buildings, the ſketch in Fig. 7. Plate 3. which is merely ideal, will be ſufficient to ſhow better than many words, what I want to have aſcertained.

3d. Whether the water cannot without difficulty be brought to the place of its fall upon a ſtill higher level, and whether the tail of the mill cannot be ſunk deeper, ſo as to increaſe the fall, an advantage in either of theſe particulars of half a foot is worth noticeing. Upon this head I muſt obſerve, I expect the lower mill within the town may have its tail race conſiderably lowered; for that reaſon I ſhould be glad to know how much its bottom is above the ordinary high water mark, not only of ſpring tides, but of the neap tides alſo. In reſpect to the Juſtice Mill, my propoſition is to conduct the water to it, not from the tail of the upper mill, but upon the level of the head of the upper mill, as far as the height of the adjacent ground will admit, and then to take it into lander troughs to convey it over the declining ground into the wheat miln: and that there may be

be no level unneceſſarily loſt in conducting the water, I ſhould be glad to know the whole fall from the lead, after it has paſſed the road next the mill-pond, to the tail of the preſent wheel, and from thence as far as the town's lands ſtand, or they have power to let it fall, noting the reſpective diſtances, as alſo how far the water can be conducted on the ſurface of the ground in the lead from the mill-pond to the mill, and how far it will be required to be carried in a trough. According to this propoſition, the upper mill may be left ſtanding as it now is, to perform the ſervice it is obliged to do: but as the water will then paſs by the wheat mill, without turning it, if this ſervice will too greatly encroach upon the wheat mill, it will be the moſt compleat way of all to fix up the mill ſtones of the upper mill, to be turned by the wheat mill wheel, as then the upper mill ſervice will be diſpatched in one-fourth of the time; but then this will occaſion ſome addition of expenſe in new conſtructing the wheat mill; yet the wheat mill may be ſo conſtructed as to admit of this addition afterwards, in caſe it ſhall be found neceſſary.

4thly and laſtly. An experiment ſhould be tried upon each ſtream of water in the following manner:—Let a board of three, four, or five feet long have a notch cut in it as in Fig. 8. of one foot wide, and about ſix inches deep, which fix in any convenient part of each of the watercourſes either above or below the mills, but ſo that no water may go through it but what is employed in turning the mill referred to; this board is to be fixed in the manner of a dam, and to be made up with earth, clay, turf, ſods or feal, ſo that all the water turning the mill may be conſtrained to go through this notch, and not to be interrupted by any water below it. The mill, in caſe it is not a time of ſhort water, is to have its water paſſing the notch ſhortened, till it is as near as poſſible, in the judgment of the miller, the ſame quantity as they let down to work with in ſhort water times; and the miller is to ſpecify how many hours in 24 they can generally grind per day in dry ſeaſons at that rate. While the water is thus going through the notch, it is to be noted, how much the dead ſurface of the water lying againſt the board on the upſtream ſide of it is below the top of the board, and to be meaſured at the diſtance of at leaſt ſix inches on one ſide the notch; this being done on each ſide of the notch at the ſame diſtance therefrom, and if any difference taking the mean, this ſubtracted from the whole depth of the notch, gives the thickneſs of the water flowing through it:—From this experiment I ſhall be enabled to calculate exactly how much buſineſs can be diſpatched by each mill.

Upon the whole, as ſtreams of water run ſcarce in the neighbourhood of Aberdeen, it ſeems of conſequence to make the beſt uſe of thoſe ſo advantageouſly ſituated.

Auſthorpe,
19th *February* 1770.

J. SMEATON.

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J. SMEATON.

Auſthorpe,
19th *February* 1770.

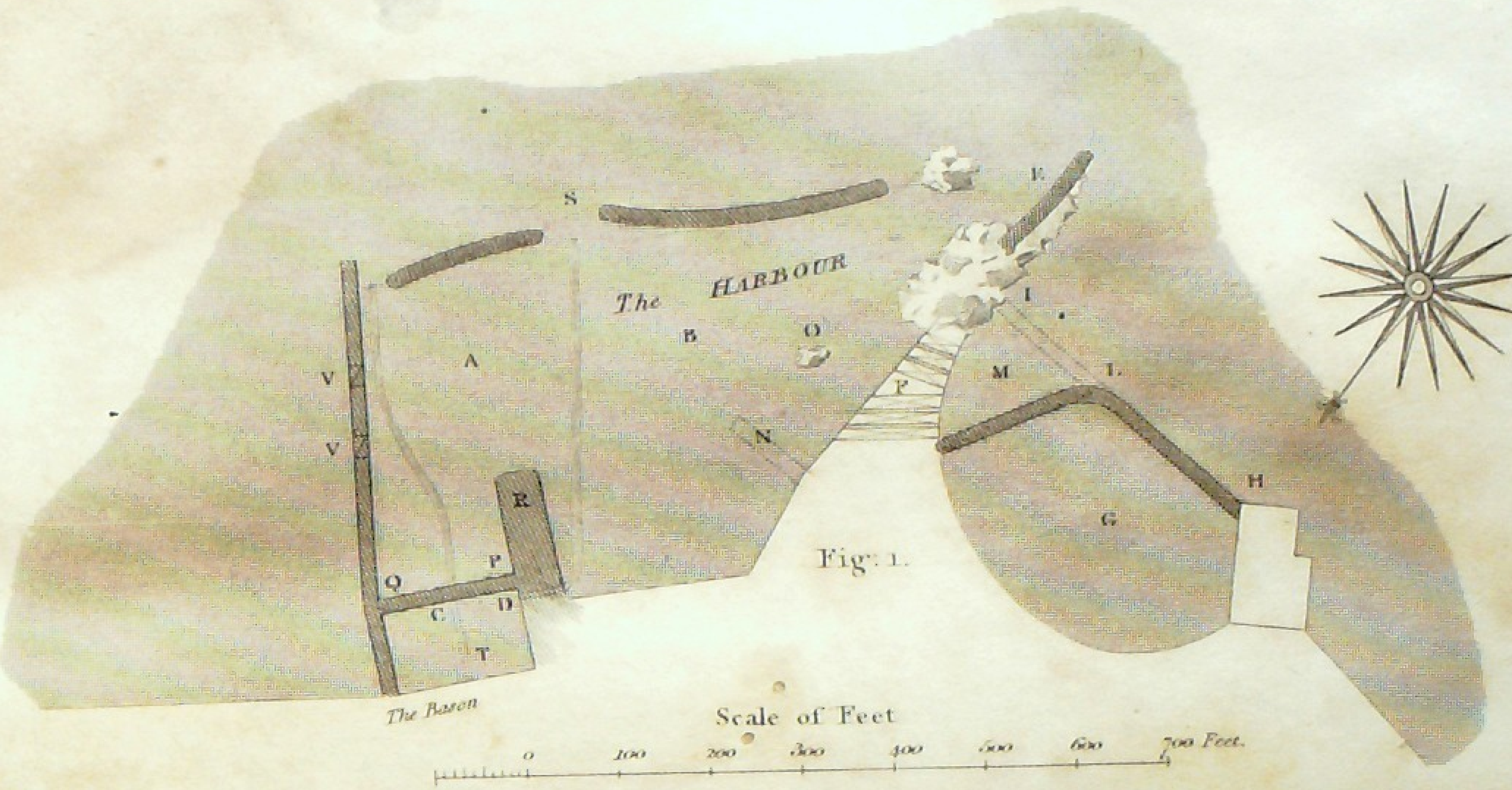
DUNDEE HARBOUR.

(See the Plan, Plate 4. Fig. 1.)

The REPORT of JOHN SMEATON, Engineer, upon the Harbour of Dundee.

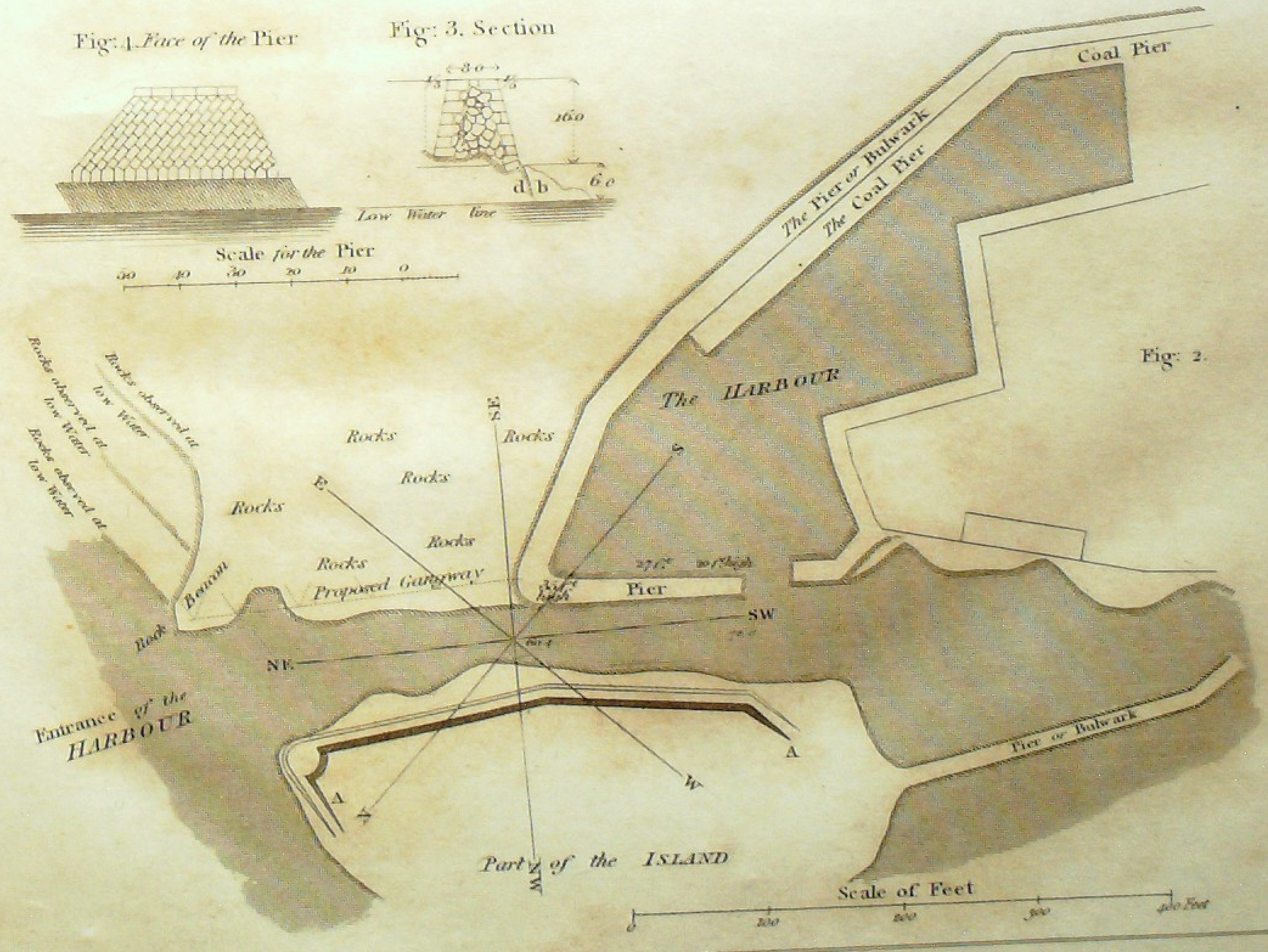
IT is a very difficult thing to make an artificial harbour to be in all reſpects complete, for the very means that tend to render it ſafe and quiet for veſſels, tend to make it leſs eaſy of acceſs, and more ſubject to mud, ſilt, or ſand, ſuch as the coaſt happens to be annoyed with. The harbour of Dundee by being too much incloſed is too ſubject to mud, and in ſuch a degree as greatly to diminiſh the ſpace incloſed, eſpecially for larger veſſels. I obſerve that the places where the mud chiefly lies are at A. and B. which are ſeveral feet higher than the entries and ſpaces near the runs of the ſluices, particularly that at B. The preſent means of clearing it are by drawing a complete quantity of water from one or other of the ſluices upon the baſon at C. or D. and by a number of men ſet to confine the current into a channel at pleaſure, and throwing in the mud, whereby it is carried without the entries, and thence taken away by the run of the tides. This operation it is ſaid anſwers pretty well as to clearing the harbour, but it is attended with conſiderable expenſe, and requires to be too often repeated. Notwithſtanding what aſſiſtance can be given by running the ſluices, when unaſſiſted by men at the bottom, it is ſaid that before the pier E. was projected ſo far, and before the Ground was made up at F. between the little bay G. and the harbour, that it was then leſs ſubject to mud, particularly at B. and indeed this very well correſponds with the reaſon of the thing, for I obſerved when there, the 4th Auguſt 1769, being the third day after new moon, and conſequently at the height of ſpring tides, that on tide of ebb a very ſtrong current ſet paſt the end of the pier E. and was diverted thereby from the harbour's mouth; of conſequence were there proper openings made in the neck at F. though they cannot be expected to clear away the mud at B. already depoſited, yet being once done by other ways, this will be the moſt likely means of keeping it clear; I would therefore recommend that this neck be pierced by two ſets of tunnels, in the directions ſhewn at F. three and three together of 12 feet wide each. They may be arched over ſo as to make good the platform at top, or by way of ſaving arching, may be ſhortened according to the dotted line at F. Thoſe tunnels ſhould be made with a clear paſſage

PLAN of the HARBOUR of DUNDEE with the alterations for improving it, by J. Smeaton.



page 57.

PLAN of the HARBOUR of DUNBAR by John Johnson with a design for amending it, by J. Smeaton.



J. Farey del.

W. Lowry sculp.

Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

paſſage as low as they can be made for the rocks, or to low water mark. The croſs wall H I. inſtead of being carried from H. to I. muſt be turned round at L. ſo as to leave open the ſpace M. of its natural depth. That the tunnels may be freely ſupplied, the preſent little pier ſhewn by dotted lines at N. ſhould be totally removed, and the rock at O. ſhould be levelled with the reſt ſurrounding it, and the whole ſo reduced as to give all freedom of water-way poſſible through the tunnels, and in this ſtate of things, if the pier E. had occaſion to be carried out ſtill further, it would bring the tide more forcibly through the tunnels.

The means above-mentioned, by promoting a more free circulation of water through the harbour, would tend to keep down the bank of mud at A.; but I cannot think it would effectually keep it clear; but I apprehend when this is once done by the help of men, as before, by a more judicious diſpoſition and application of ſluices upon the preſent baſon, the whole harbour may be kept in a great meaſure free. In the firſt place, I apprehend the water-ways of the ſluices are much too ſmall, for though the baſon itſelf is much ſmaller than were to be wiſhed, yet the letting the water go off in a ſmall body though continued a longer time is not making the beſt uſe of it: a certain power of water will move that very expeditiouſly, which applied in a leſs degree will let the ſubject remain at reſt. Conſequently, the water being diſcharged from the baſon in a large body, will do that in five minutes, which would remain undone, if the capacity of the opening were reduced ſo as to play a quarter of an hour; for this reaſon I would adviſe the ſluices to be full three feet ſquare in the orifice, and to be laid rather lower than the bottom of the baſon. The ſluice D. may ſtill remain the place for one of them, but inſtead of the ſluice C. I would adviſe two upon that line at P. and Q. of the dimenſions aforeſaid: That at P. will more directly tend to ſcour the face of the pier R. than in its preſent poſition C. and alſo to keep down the growth of the mud at A. and more eſpecially if a paſſage be firſt opened for it, to vent its water by the opening S.; but the ſluice P. being ſo much nearer the pier R. it will be ſo much farther from the eaſt pier; to keep the face whereof clear, it will be proper to have the other ſluice mentioned at Q. which will alſo ſerve a ſecondary uſe; for as the baſon itſelf is liable to fill with mud, which I ſuppoſe it is a conſiderable expenſe to remove, this may be prevented by building a croſs wall according to the dotted lines, with a ſluice upon it at T. of equal ſize or rather larger than the others, conſtructed ſo as to pen the water either way; this ſluice may therefore be made uſe of by penning the water in one half of the baſon to ſcour the other, and ſo alternately; and when open ſuffers the whole baſon to act by any of the interior ſluices; to avoid loſs of water, it will be proper to have all the ſluices, particularly thoſe at Q. P. and D. executed in the moſt ſubſtantial manner. I cannot

cannot advise the doors to be cut, in order to make a valve to let the water in, but rather to set one of them open by hand; and to prevent accidents by neglect, a small tunnel with a valve in part to let in and effectually to keep in the water, may be fixed in the present opening at C. This I think will be the most effectual way of applying the water of the bason without the use of men, and I think it would also add, if to the opening in the east pier, which if I remember right is there already, there were another added, not less than 25 feet wide, so that they may be nearly in the position V V. By these means, I expect the harbour may, when once cleared, be kept clear, or so nearly so, that with a little help from men occasionally, to direct the water to particular places, it may be effected in the most easy manner that the situation will admit of.

J. SMEATON.

N. B. To prevent loss of room in the bason by the cross wall, it may be a strong stone wall, well built with lime, and aislered on the two outsides.

DUNBAR HARBOUR.

(See the Plan, Plate 4. Fig. 2.)

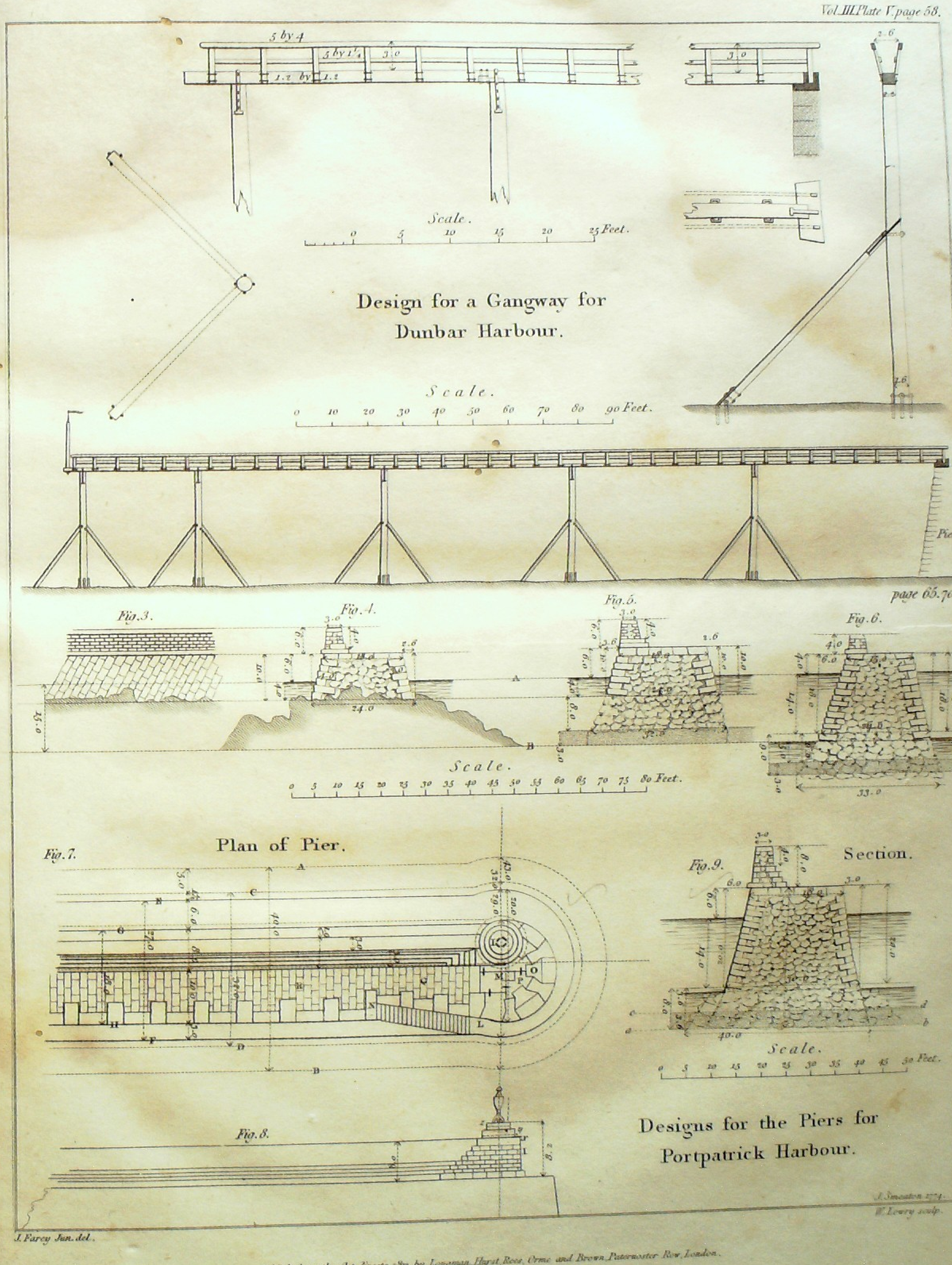
The REPORT of JOHN SMEATON, Engineer, upon the Harbour of Dunbar.

THE harbour of Dunbar appears from its form to be well adapted for the security of vessels lying therein, and as it is situated in the bottom of a bay, exclusive of the trade that is usually carried on there, it becomes of consequence to the security of vessels trading on this coast; and its principal deficiency in both these views is the want of a good access, particularly in going into it; and this is not owing to an improper course or direction of the entry from the bay, but from the narrowness of the passage, which is rendered in effect still narrower from the sloping form of the rocks on the starboard or N. W. side going in, to avoid which, vessels are obliged in prudence to keep nearer to the pier than they otherwise would do, and by this means, by the recoil of the sea from the rocks, are often driven against the pier, or upon the sloping rocks that are sunken and hid. To remedy this inconvenience as much as possible, it has been very properly proposed to cut off a certain part of the slope of the rocks, down even with the bottom of the rest of the passage, and to build the face up above high water mark, (as shewn at A A. in the plan), by which means, as the passage will not only be actually widened full five yards in the narrowest place, but by giving opportunity to vessels to see every thing that can hurt them, they may safely keep several yards further from the pier than they could otherwise have done; the passage thereby in the narrowest part being rendered from about 45 to 60 feet wide; at the same time the sea being prevented from breaking upon the sloping rocks, it will recoil with less force than at present, and the vessels will be less subject to be carried from side to side for want of sufficient way through the water. Lastly, this new pier or facing to the side of the entry being carried up sufficiently above high water mark, it will enable assistance to be given by throwing a rope on board from the most projecting point thereof, so as to tow in vessels when they do not come in with sufficient fresh way, to keep them clear of either side of the entry.

With the same view it would be well if a pier could also be carried out upon a ledge of rocks (which are dry at low water) on the S. E. side of the entry from the north angle of

of the present pier, to the Beacon Rock. This would not only defend the paſſage from the ſurge of the ſea, but by its projection alſo enable aſſiſtance to be given by throwing a rope on board on the larboard ſide of the ſhip, of which there is always an equal chance of its being preferable, by its being neareſt; and ſtill more effectual when it can be done on both ſides. To this however may reaſonably be objected the great expenſe that muſt neceſſarily attend the execution of a pier of ſufficient bulk and ſtrength to ſtand in this place the full ſtroke of the ſea: however, to take advantage of that part of the utility of a S. E. pier, which conſiſts in giving aſſiſtance by a rope, I have contrived a gang-way to extend itſelf in the ſame direction as far as the Beacon Rock, as ſhewn by the dotted lines in the plan, whereby any competent number of men will be able to give the ſame aſſiſtance by heaving a rope on board, as could be done from a ſtone pier, and which is contrived on principles ſo ſimple that it may be executed at a very moderate expenſe. This will be ſufficiently explained by a deſign on purpoſe, (ſee Plate 5.) ſhewing how the ſame is to be executed, and indeed, had I not a good deal of experience in the of fixing temporary utenſils in the building of the Eddyſtone Lighthouſe, I ſhould have been very dubious in propoſing a ſtructure ſeemingly ſo ſlight to ſtand the violence of the ſea. But there I learnt, that where the force of the ſea is to be rather eluded than reſiſted, the leſs matter is oppoſed to its action the better, provided that this be but fixed in the firmeſt manner. I believe the whole of the deſign will occur from the plan, ſave the manner of fixing the iron bolts into the rocks, which are not propoſed to be done with lead, as that is perpetually working looſe, but in the following manner:—Round holes about 18 inches into the rock more or leſs, according to the firmneſs thereof, are to be bored with a jumper of $1\frac{1}{2}$ inch diameter; to theſe the eye-bolts are to be forged a very ſmall matter taper, and larger ſo as to drive tight to their proper depth, with an iron maul; if they happen to be a ſmall matter too ſmall, then ſtrips of plate iron put in along with them will make them to drive firm, and the ruſt will fix them from drawing.

Reſpecting the propoſed pier or wharf (A A in the plan), as it will receive the full ſtroke of the ſea, with a S. eaſterly wind, it will be neceſſary to be built very firm, and I believe it will not fully anſwer the end if the ordinary ſeas break over it; I therefore propoſe it to be raiſed nine feet above high water at ſpring tides, that is 22 feet above the low water line at the pier head, but it may decline in height as it runs S. weſtwards towards the land. This height will carry it conſiderably above the rocks where it is built, and therefore inſtead of ſo large a quantity of backing as will be neceſſary to make the whole good to that level with the land, I have propoſed it to be built upon the back ſide as per ſection, Fig. 3. The rocks b. at the foot of the pier, are to be taken away as above ſhewn, before the



the pier is built; and when it is finifhed, they are to be cut off fmooth according to the line a.

The bare ftones of the pier (fee the face view, Fig. 4.) are not propofed to be all on the fame level, as there fhewn, but the rock cut to give the ftone its proper bearing.

The face (Fig. 4.) if you can procure the free-ftone at a moderate price, will be beft done according to the fpecimen; but if you work with rough ftones, the more nearly they are laid conformable to the fame idea, the better; and the platform at top fhould be laid on with the beft mortar. As I cannot well judge of the prices at which the materials can be procured, and the work executed at Dunbar, I content myfelf with making an eftimate of quantities as follows, which may be fitted up after proper workmen &c. are confulted.

ESTIMATES.

THE PIER.	£.	s.	d.
To cutting the rock according to the line in the plan 786 cube yards at -			
To building in the whole pier 2,770 cube yards at - - -			
To free-ftone in the face and platform, reckoned at a medium $2\frac{1}{2}$ feet in thicknefs, reckoned extra in its value in the folid of the pier 26,250 cube feet at - - - - -			
To pofts of wood or ftone (if thought neceffary), as alfo for lime &c. -			
To contingent expenfes at 10 per cent on the above articles - -			
Total of the pier £			

THE GANGWAY.			
To fir timber 942 fay meafured neat in place 1000 cube feet at -			
To iron work $19\frac{1}{2}$ cwt. fay one ton at - - -			
To a large ftone for fixing the end of the gangway to the parapet of the prefent pier, 30 cube feet at - - -			
Contingencies on the above at 10 per cent. - -			
Total of the gangway £			

Auftborpe,
25th *June* 1772.

J. SMEATON.

PORT PATRICK HARBOUR.

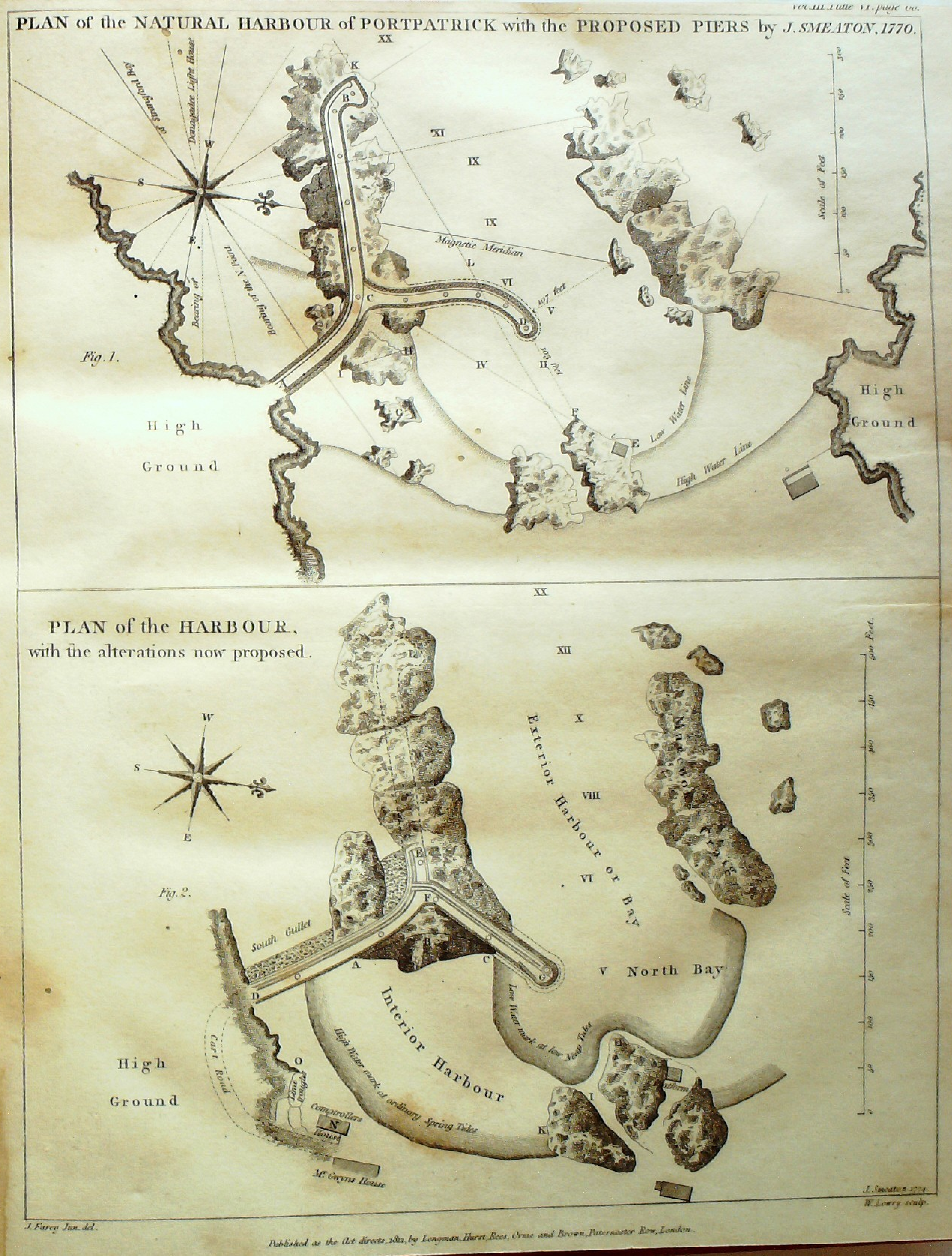
The REPORT of JOHN SMEATON, Engineer, upon the Harbour of Port Patrick, in the Shire of Galloway, with a Projection of Piers for rendering the same safe and commodious for Vessels of eight feet draft of water.

THE harbour of Port Patrick is generally efteemed the neareft port in Great Britain to Ireland, being, as it is faid, but about feven leagues from the harbour of Donaghadee, upon the coaft of Ireland, and which is almoft right oppofite: on account therefore of the fhortnefs of the paffage, it becomes a very defirable object that the harbour of Port Patrick fhould be rendered fafe and commodious for fuch veffels as are beft adapted to carry the pacquets, paffengers, carriages, horfes, cattle and goods between the two kingdoms; and on this head I am advifed, that nothing lefs than veffels of 40 tons, drawing eight feet of water, and conftructed upon proper principles for failing, will be fully adequate to this purpofe.

The harbour of Port Patrick is at prefent entirely in a ftate of nature, a fmall platform for the more commodious landing and fhipping of paffengers, &c. excepted; and indeed it has many natural advantages, being very eafy of accefs, and of fufficient depth to ride the veffels proper to be employed afloat at low water, and to protect them from ftorms coming from feven-eighths of the whole compafs; and had the remaining eighth been as well guarded as the reft, this harbour had been complete; but the want of protection from thofe points, neceffarily obliges the veffels employed to be of fuch a conftruction as unfits them for the general purpofes. Thofe defects it is the bufinefs of art to remedy, which is the object of the prefent propofition.

This harbour is formed by two ledges of rocks running out almoft parallel from the fhore, fo as to form between them a fmall bay of about 220 feet clear width, and about 550 feet in depth, that is in and out. The bottom is a clean fand, and the foundings gradually increafe from the fhore to 20 feet at low water in the mouth of the bay, and leaving from 9 to 10 feet at dead low water mark in middle of the harbour.

The



The coaſt of Ireland lies right in front, extending from S. W. to N. W.,* and being ſo near as not to admit of any conſiderable ſwell with the wind right in, it becomes naturally defended from the weſtern quarter. From the N. W. & N. points, the fetch of the ſea is not of great lengths, being in a manner land-locked by the Ila, Mull of Cantire, &c. and being laſtly very well ſkreened by the ledge of rocks immediately on the north ſide of the harbour, which riſe conſiderably above high water, no conſiderable violence is experienced on that ſide. The land lies from N. to S. ſo that nothing can happen from the eaſtern point; it is therefore only from S. to S. W. incluſive, that the harbour lies unprotected.

The ledge of rocks on the ſouth ſide of the harbour, which run out in a direction W. by S. and nearly point toward the lighthouſe of Donaghadee, would from their poſition afford a conſiderable ſhelter in all thoſe winds, if they were higher ; but the Iriſh ſea being open from theſe points, and the rocks being in a great meaſure covered at high water neap tides, and at three-fourth flood at ſpring tides, the ſeas break over them with ſo much violence in time of ſtorms, that veſſels lying there are obliged to be ſuffered to beat up upon the ſandy beach, at the bottom of the bay, and to be retained by ropes as the only means of protection ; this in conſequence not only creates a great deal of trouble in hauling them up, and launching them after the ſtorms are over, but obliges them to be made ſo ſtrong and of ſo flat a conſtruction, that they will not ſail except with wind on the beam or abaft. As therefore all the weſterly winds prevent their ſailing from Port Patrick to Donaghadee, and all the eaſterly from returning, it follows that they cannot regularly go and return except the winds are ſoutherly or northerly ; nor indeed could they go very well with thoſe, were it not for the very ſtrong current of the tides which ſet up and down this narrow channel, between the two kingdoms, twice each way in a day ; ſo that by ſailing at a proper time of tide, they are prevented by the current from falling to leeward : but could veſſels conſtructed upon proper principles for ſailing be protected here from all points, they would be enabled to turn to windward, and conſequently make their paſſage good in all winds when the weather is moderate, from the great advantage that ariſes from the particular ſet of the tides.

Now, as this harbour in its preſent ſtate would be very convenient for the purpoſe, being open and deep, and eaſy of acceſs and departure, were it not on account of the effects of violent winds from one-eighth part of the compaſs only, as before mentioned, the place

* All the bearings in this report are according to the compaſs, the north point of which is ſuppoſed to vary about 24 degrees to the weſt.

itſelf

itſelf being ſmall, it muſt be a principal care, that while we are providing againſt the above mentioned difficulties we do not deſtroy its natural advantages. With this view I propoſe to run out a pier from the point of the rocks upon the main land at A. Fig. 1. Plate 6. and croſſing the gully between that point and the detached ledge of rocks hitherto called the South Ledge, to follow the general direction of the ſame, and to terminate the pier at B. as particularly ſhewn in the plan. This pier to be raiſed ſix feet above the high water of a ſpring tide, with a parapet of ſix feet upon that; ſo that the whole being raiſed 12 feet above high water, will effectually ſcreen the veſſels from the S. & S. weſterly winds, and greatly mitigate thoſe nearer the weſt; and ſo far as this goes, the benefit to be obtained will be attended with no diſadvantages in other reſpects, that I can foreſee; and it is poſſible this being firſt executed, the internal pier may be found unneceſſary; but as the north point of Strangford Bay on the coaſt of Ireland is the ſouthernmoſt bearing from Port Patrick, viz. S. W. $\frac{1}{2}$ W. diſtant about nine leagues by the maps; when the wind s a little further out than this, viz. S. W. I am of opinion that ſo much ſea will get round the head as to reduce the ſpace naturally ſcreened thereby into ſo narrow a compaſs, that veſſels properly built for ſailing will not ſafely ride in the harbour with the wind in ſuch poſition, as may be judged of by conſidering the poſition of the line upon the plan, marking out the bearing of the north point of Strangford Bay. It ſeems therefore neceſſary to provide a place of ſafety at ſuch times, which I propoſe to effect by means of the interior pier C. D. the poſition of which I have endeavoured ſo to adapt, as to be ſufficiently capacious and deep, and without taking up any part of the external harbour, where I apprehend the veſſels uſually ride. This would have certainly been the caſe, had this internal pier been carried further out, ſo as to have been capable of admitting veſſels drawing eight feet at low water; as it is, all the ſpace is preſerved where they cannot in ordinary float at low water, and veſſels will be capable of going in and out of the external harbour at all times, except from three-quarter ebb to one-quarter flood; and during this ſpace of low tide, the ſeas will be ſo mitigated by the projection of the rocks upon the neighbouring coaſts, that a veſſel may ſafely ride in the external harbour, till the water flows ſufficiently to let her go into the internal. It is true, that as the veſſels in the internal harbour will be obliged to take the ground, they will be required to be ſtrong timbered; but as they are not intended principally to carry weight, that will not hinder their external form from being adapted in the beſt manner for ſailing, it being the caſe with few harbours the moſt reſorted to in Great Britain, that veſſels can ride afloat at low water.

The flow of the tides at Port Patrick is ſaid to be 15 feet at ſpring tides, and 12 feet at neap tides, but like other places variable according to the winds. When I was there, which

which was on the 11th of October 1768, being the day after the new moon, the perpendicular flow was only 10 feet, ſo that at a 15 feet ſpring tide the water would ebb out $2\frac{1}{2}$ feet lower, as appeared by a mark pointed out to me, and flow $2\frac{1}{2}$ feet higher; according to this ſtate of the tides the internal pier will be placed at $4\frac{1}{2}$ and 5 feet water, at low water ſpring tides, and will have $19\frac{1}{2}$ and 20 feet at high water, and at ſuch a tide as I ſaw (which was leſs than an ordinary neap tide), 7 and $7\frac{1}{2}$ at low water, and 17 and $17\frac{1}{2}$ at high water; ſo that it is evident veſſels will be always afloat within the internal harbour, whenever it is a proper time of tide to go out, there being always 12 feet water at half tide.

This internal pier being at all times greatly ſheltered from the violence of the ſeas by the external one, it is propoſed to be conſiderably thinner on that account, and its body not raiſed ſo high by two feet, ſo that its top will be lower in the whole by four feet; that is, it will be only eight feet above high water ſpring tides; yet this it is preſumed will always be fully ſufficient to reſiſt any ſeas that can get round the head of the external pier.

Since I have propoſed the internal pier as a place of refuge, it may be reaſonably enquired why this may not do without the external one? To this I muſt obſerve, that it is only ſo much of the external pier as projects beyond the internal one, that is the object in queſtion; and this will be built with ſo much advantage to a proper height by being upon the rocks, that if omitted the internal pier will be required of greater baſe, height, and ſtrength, and thereby the coſt of the external one will in a great meaſure be incurred.

2dly. The veſſels will be protected in the external harbour with wind at S. and S. S. W. and therefore can come in and find ſhelter, at a time when the tide would not ſerve to go into the internal harbour, and alſo will ſo far moderate the ſeas at S. W. as to enable the veſſels to wait till they can get into the internal; and in all ſoutherly winds will enable veſſels to get under way going out, and to come to on entering, when they could not venture to do either from or to the entry of the interior harbour.

3dly. If the ſeas were not firſt moderated by the external pier, ſo much ſea would get round the internal as not to admit veſſels to lie there with ſufficient quiet, unleſs it were ſo far contracted in the entry as to make it difficult of acceſs and departure.

Within

Within the internal pier the veſſels may occaſionally take in their freight; but as I apprehend the place of the preſent platform will be found in general the moſt commodious, eſpecially about half tide, I propoſe that platform to be extended, and the face of the rock to be extended, by blowing off the irregularities according to the line E F. and if the rock G. and part of the rock H I. to that line, be blown up to the level of the ſand, it will be a means of preventing damage to veſſels within, and of entertaining a greater number of veſſels, for when this is done, the interior harbour will be capable of holding, on occaſion, 10 or 15 ſail, from 40 tons downwards.

Reſpecting the conſtruction of the piers, as the coaſt is all rocky, I propoſe to make all the uſe that properly can be done of the ſtone that the place affords, but it happens to be of a kind not very well adapted for this ſort of work, except for fillings and rough baſements of ſuch parts of the piers as are not built upon the rocks, and to theſe uſes I propoſe to confine it. The ſtone compoſing the two ledges of rocks on each ſide of the harbour is of a very hard but very jointy nature, which ſeems a good deal the caſe with the ſtone I ſee thereabouts, ſo that it can hardly be got without gunpowder, which would be apt to ſhiver it into ſmall pieces. I obſerved that a conſiderable quantity of large looſe pieces that have tumbled from the cliffs may be collected, enough to form the baſements of the piers as marked out in the ſections, Plate 5.; but as it does not appear that a ſufficient quantity could be collected to do the whole with rough materials, which would, if ſo conſtructed be required to be ſtill more bulky, I propoſe to face the upper part of the piers with quarried ſtones, ſcapelled to ſomewhat of a ſquare form, to be diſpoſed as ſhewn in the ſections, and to be filled with rough materials to be obtained from the rocks in the neighbourhood. I did not indeed ſee any ſtone in that part of the country fit for facings of the kind I propoſe; but as this part lies open by ſea to a conſiderable extent of coaſt of England, Scotland, and Ireland, it is not to be doubted but that convenient quarries of proper ſtone will be found that can be brought by water, and for this purpoſe I have made a conſideration in my eſtimate of 2s. 6d. per ton, that will be about 2d. per cube foot, which allowance I judge fully ſufficient.

It is further to be obſerved, that I propoſe all the rough baſes and fillings to be compoſed of as large ſtones as can eaſily be procured near the place, and no ſtones of two tons or under be broken on account of removal; and that the fillings be at a medium, about a cube foot in a piece, the ſmaller being diſpoſed in the interſtices. The whole to be built dry, except what is particularly ſpecified in the eſtimate to be done with cement or mortar.

It

It has been obſerved to me that a conſiderable rivulet can be turned into this harbour; this may be of great uſe in caſe the interior harbour ſhall be found inclined, from a greater degree of confinement, to retain more ſand than it does at preſent, and will prove an effectual remedy to every evil that can ariſe from that circumſtance. At preſent the harbour does not retain more ſand than one would wiſh it to do, for the ſafety and eaſe of veſſels.

Austhorpe,
18th *May* 1770.

J. SMEATON.

EXPLANATION of the Plan of Port Patrick Harbour.

Fig. 1. (Plate 6.) Plan of the natural Harbour, with the projection of the propoſed piers:—The Roman figures expreſs the depth in feet of the low water of a ſpring tide, the perpendicular riſe of which is ſaid to be 15 feet and the neap tides 12, conſequently at neap tides low water, there will be 1½ feet more water than the ſoundings expreſs. The bottom is clean ſand.

AB The exterior Pier.

CD The interior Pier.

EF The line in which the face of that rock is propoſed by blowing to be ſtraightened, and to have timbers bolted to the face of it, to make the landing place there more commodious; the platform may alſo be extended to *e. f.*

G A rock to be blown to the level of the ſands; and

H I Another to be blown to this line, in order to clear the interior Harbour.

The line K L ſhews the bearing of the north part of Strangford Bay, upon the coaſt of Ireland, being according to the map 9 leagues diſtant.

Fig. 3. (Plate 5.) Shews the outward face of the Pier on the ſouth rocks; and

Fig. 4. Do. A ſection of the ſame, ſhewing the manner of building it with quarried ſtone, and filling up with rough ſtones.

Fig. 5. Do. Section of the Pier acroſs the gully, between the ſouth rocks and the ſhore.

Fig. 6. Do. Section of the interior Pier:—All theſe figures are placed to ſhew their relative levels to high and low water lines (A & B) at ſpring tides.

ESTIMATE

ESTIMATE for building the Piers of the Harbour of Port Patrick, according to the designs of John Smeaton Engineer.

The EXTERIOR PIER.

		£	s.	d.
To form a basement of rough stones, to be collected from the adjacent coast and cliffs in order to make up the gully between the main land and the ledge of rocks on the south side of the Harbour, to be 32 feet mean base, 24 feet top, and 8 feet mean height, length 120 feet, will contain 1000 cube yards, which at 7s. 6d. per yard - - - -		375	0	0
The upper part of the Pier being supposed a medium 10 feet high, extending from the land 400 feet; the mean thickness of the facing on the outside of the Pier being 3 feet 3 inches, and the inside 2 feet 9 inches, will contain cube feet - - -	24,000			
To make good the platform at top, being the same length, 12 feet broad and 1 foot thick - - -	4,800			
Cube feet of stone at 10d. per foot complete - -	28,000	1,200	0	0
To 2,044 cube yards of rough stone in filling, at 5s. - -		511	0	0
The circumference of the Pier head for 40 feet in length next the head, will be 112 feet, this at the mean thickness of 3 feet 6 inches, and 10 feet high, will produce cube feet - - -	3,920			
And to make good the platform to the above - -	1,120			
Cube feet of stone at 10d. per foot - -	5,040	210	0	0
To rough stone in filling 40 feet length, next the head, 332 yards at 5s. -		83	0	0
The length of the front wall of the head being 40 feet, 15 feet in thickness, and 10 feet high, contains 222 cube yards; this being laid in cement, will, with extra labour and materials, at 7 shillings, come to - - -		77	14	0
To cutting footings for the bases of the outside casings to rest on, 1,540 feet superficial, at 1 shilling - - - - - -		77	0	0
To 440 feet of parapet in mortar, at £1. per foot - - -		440	0	0
		£ 2,973	14	0

The

The INTERIOR PIER.

		£	s.	d.
To the forming a basement without the rocks of rough stones, 33 feet base, 25 feet top, and 9 feet high, supposed to reach one foot above low water, and to settle 3 feet into the sand; this, in a length of 180 feet will contain 1,740 yards, at 7s. 6d. - - - -		652	10	0
The height of the casing being 18 feet mean thickness, of the outside 2 feet 9 inches and 1 foot 9 inches, inside 2 feet 4½ inches; this, in a length of 180 feet, will contain cube feet - - -	16,605			
The height of the casing over the rocks to join the former to the main pier, being 8 feet, will at the above thicknesses and 70 feet long contain - - - -	2,870			
To make good the platform in the whole length - -	2,500			
	21,975	915	12	6
To rough fillings in that part of the Pier without the rocks, cube yards	1,658			
To Do. in the part over the rocks - - -	220			
Cube yards of rough filling, at 5s. -	1,878	469	10	0
To cutting the footings upon the rock, 280 feet, at 1s. - -		14	0	0
To walling 5 yards, running next the head, in cement, containing 200 cube yards, extra labour and cement, at 7s. - - - -		70	0	0
To 240 feet of running parapet in mortar, at 15s. - -		180	0	0
The Interior Pier - -		£ 2,301	12	6
The Exterior Pier - -		2,973	14	0
Neat computation - -		£ 5,275	6	6
To contingent expenses, in iron work, fender piles, stairs, blowing of rocks, machines, &c. being 10 per cent. upon the above - -		527	10	0
		£ 5,802	16	6

J. SMEATON.

Authorpe,
18th *May* 1770.

EXPLANATION

EXPLANATION of the Plan for completing the Interior Harbour at Port Patrick.

THE work being now advanced sufficiently to the weſt to break off from that part intended for the interior Harbour, the great ſeas that roll in with the ſoutherly and ſouth weſt winds, what is principally wanted to ſecure the veſſels lying under ſhelter of the preſent work, is a flank Pier to prevent the ſeas from returning laterally after they have paſſed the head, and then following the back ſide of the Pier and ledge of rocks into the place of the interior Harbour.

For this purpoſe, and by reaſon that it is found expedient to complete the interior Harbour before the exterior Pier is carried further out, I have projected the Pier deſigned in the preſent Plan in ſuch a way, as that it may in the beſt manner anſwer the end, on ſuppoſition that it may not be found expedient to carry out the external Pier further than it extends at preſent.

I have therefore deſigned it in ſuch a poſition that veſſels, when coming from ſea, may run into the interior Harbour under ſail, leaving the bottom of the little Bay Road Stead or exterior Harbour as diſencumbered as poſſible, to be uſed in moderate weather, and when a greater degree of ſhelter and protection is not neceſſary for the ſame purpoſe as at preſent; and at the ſame time having the acceſs to the interior Harbour as free as poſſible, that time may not be loſt in getting in and out of it.

The poſition of the propoſed interior or flank pier, is nearly N. E. by the compaſs, and extended from the main pier 175 feet, ſo as to leave about 100 feet of opening between the Pier head and the neareſt point of the platform rocks, which rocks will in effect anſwer the end of a counter pier. This poſition and length, by admitting of an opening of 100 feet, will enable veſſels to get under ſail in bad weather, that is, whenever they can venture in between the two ledges of rocks that compoſe the exterior harbour, and will prevent the lateral return of the ſouthweſt ſeas into the interior harbour, and throw them into the bottom of the north Bay, ſo as to ſpend themſelves upon the beach. It is in conformity with this poſition of the Pier, and in order to afford room within the harbour, as well as to give the whole of the inſide ſuch a curve as may more effectually clear off the ſands that may occaſionally be brought in, that it is propoſed to cut the rocks to the arch ABC. (Plate 6. Fig. 2.) It is alſo with this view that an opening of 100 feet is propoſed to be left; for though it will always hold true, that the leſs the mouh of a harbour is, the quieter it will be proportionably within; yet as the getting clear of ſand, the getting ſafely in during bad, and eaſily out in moderate weather, are conſiderations of the greateſt conſequence; and it being impoſſible in ſmall harbours to unite every advantage, it ſeems to me that the preſent plan will be likely upon the whole, to anſwer the end in the completeſt manner poſſible; that is, for ſheltering veſſels from 30 to 40 tons and under, which it is ſuppoſed will be fully ſufficient for the pacquet and paſſage veſſels attending at this place.

At preſent I underſtand that the place of the interior harbour keeps itſelf as clear of ſand as is neceſſary, that the rocks may not become bare, and the veſſels lie unſafely; but when it becomes more incloſed by the erection of the flank pier, as it may not then clear itſelf of ſands ſo effectually, the bringing in of the burn occaſionally in the way that has been already mentioned, by the gardener of the collector of the cuſtoms, I do not doubt will be effectual to keep it clear.

I have alſo endeavoured to make the pier ſubſervient to ſome purpoſes, which, though ſubordinate, will yet be found very convenient if not neceſſary.

I have propoſed to terminate the parapet by a round pillar of nine feet diameter, at the top of which may be planted a flag-ſtaff in order to hoiſt a flag when there is a certain number of feet of water within the pier head, or by planting a light in a lanthorn or lamp fixed upon a proper iron ſtanchion, veſſels approaching in the dark will not only with more certainty make the bay, but turn the pier head in caſe they wiſh to enter the harbour.

I have alſo deſigned a ſtair near the pier head inſide, to which a boat can always go even at low water, and thereby paſſengers be commodiouſly conveyed on board or landed at all times of tide. Mooring poſts are alſo propoſed and marked at proper intervals; and as a poſt near the extremity of the main pier may be very convenient for the faſtening or ſteadying veſſels in the bay or exterior harbour, a paſſage is purpoſed to be made by an archway of two feet and a half wide, and four feet and a half high, at the joining of the flank pier's parapet to the preſent one.

The ſpring tides are ſaid to flow here 15 feet, ſo that there will never be leſs than eight feet water within the pier head at half tide.

N. B. The projection of the main pier weſtward of the junction of the flank pier, will greatly contribute towards breaking off the ſeas from the harbour's mouth.

J. SMEATON.

Austhorpe,
6th *January* 1774.

P. S. It may be problematical till the flank pier is far advanced, whether it may be better to cut off the point of the rock marked I K, Fig. 2. by the dotted line or not. It will undoubtedly render the paſſage in more perfectly clear if cut away; but as it may tend to catch the ſwell that will in ſome degree roll in between the pier head G and the point of the rock H, this operation is left till the effect of the flank pier is ſeen.

EXPLANATION of the Plan, Fig. 2. Plate 6.

A B C The line to which the rocks are propoſed to be cut away.

D E The preſent pier as now terminated.

E L The extenſion as at firſt propoſed.

F G The interior or flank pier as now propoſed.

G H The opening between the pier head and the neareſt point of the platform rocks, being about 100 feet.

I K A line in which that point of the rock may be cut off, in caſe it ſhall be found uſeful when the effect of the flank pier is ſeen.

N. B. The Roman figures ſhew the ſoundings in feet at low water mark.

N Comptroller's houſe. O lime troughs.

Fig. 7. (Plate 5.) A plan of the intended pier F G in Fig. 2. Plate 6.

— 8. Elevation of the ſame.

— 9. Section of the ſame.

A B Is the breadth of the pier upon the rough ground baſement 40 feet.

C D The breadth of the rough ground baſement at about one foot above low water, 32 feet.

E F The baſe of the pier at the bottom of the freeſtone work, 27 feet.

G H Shews the top of the cap or platform of the pier, 18 feet.

a b Fig. 9. the ſuppoſed ſurface of clay or hard matter.

c d Suppoſed ſurface of the ſand.

X Y Z Fig. 8. The terminating pillar of the parapet capped with three circular ſtones, the two upper ones are ſuppoſed to be each ſingle ſtones, the lower one of 2, 3 or 4 pieces, as moſt convenient, the reſt of the pillar to be built as the outſide of the parapet.

L N Fig. 7. ſhew the ſtairs inſide the pier head.

O P Q R Shew the manner of forming the cap of the pier, being terminated with dovetailed ſtones in the manner of the Edyſtone, to bind the cap together.

M A poſt or pillar for warping veſſels into and out of the harbour.

DIRECTIONS

DIRECTIONS to Mr. Gwin, for the execution of the interior or Flank Pier for completing of the interior Harbour of Port Patrick.

THE middle line of direction of the baſe of this pier runs from a point about 45 feet from the weſternmoſt termination of the top of the preſent pier, meaſured inſide toward the eaſt to another point about three feet from the ſouthweſt angle of the platform, meaſured along the ſouth ſide, alſo toward the eaſt, which line of direction will be nearly N. E. by the compaſs; and as the width of the pier at its baſe will be 40 feet, it will be proper to fix up leading marks from the preſent pier to the ſhore parallel to the above mentioned middle line of direction, at the diſtance of 20 feet on each ſide of it, ſo that a perſon ſtanding at either end of theſe leading marks may be able to direct a perſon on board a veſſel afloat, to drop ſtones in thoſe lines, which are to form the extremity of the baſe.

It will be proper to have the ſtones ſo to be dropped (which are to be large pieces of rough rocks) ſuſpended by tackles in ſlings, yet not to hook immediately by the ſlings, but by a loop made of as many turns of marline or rope yarn as will hold it, and then by cutting the loop when the ſtone is in its proper poſition, it will be ſure to be dropped in the outline. The ſtones to form the internal part may be any how tumbled overboard, ſo as to be within the area formed by the outlines.

It is ſuppoſed that the firſt and perhaps the ſecond ſet of ſtones ſo dropped will bury themſelves in the ſand, and the ſooner or later according as there is more or leſs ſurge of the ſea breaking upon the place where they are depoſited; but notwithſtanding the firſt, ſecond, or third ſet of ſtones diſappear, yet by repeating the dropping they will at laſt ground themſelves upon the clay or gravel, and thoſe dropped upon them begin to appear above the ſand, and at laſt above the ſurface of the water at low water. But it is to be noted, that every ſubſequent ſett of ſtones dropped to form the outline, muſt be nearer the centre line than the preceding, ſo that a ſlope ſomewhat like that ſhewn in the ſection may be formed. As to the interior parts they may be tumbled in promiſcuouſly, and if they begin to appear in ſome places before others, the defective places may be afterwards ſupplied. The more rough weather you have in the courſe of making this baſement, the more ſolid your work will be, as it will be the more firmly or the more deeply grounded upon the harder matter, and prevent after ſettlements, and in caſe any part of the work ſettles after it has appeared you muſt ſtill fill up the addition by freſh matter.

The

The diameter of the circular part of the head being two feet greater than the common breadth of the pier, the basement may be broader by one foot and a half each side, that is, 43 feet over all; and having determined the extremity of the basement of the head by cross marks at or about 88 feet from the nearest point of the platform rocks, this cross line with the others will be sufficient for dropping the foundation of the head in somewhat of a circular form, correcting it as you see it, for when you get the pier head to appear above low water, you then can mark off an actual centre and work by real lines.

As you have not said at what depth below the surface of the sand you found the clay, gravel, &c. I have supposed in the additional drawing, Fig. 7 & 8, (Plate 5.) that the sand lie three feet and a half below the surface of the water at low water, and the clay three feet and a half below the sand, so that from the solid matter to low water mark is supposed 7 feet; if it happens to be more in any or every part, the width of the ground tier of stones must be proportionably increased; if less, you may diminish it at discretion, but in general it is good to keep a good breadth upon the ground.

It is probable that at low water you will find the stones stuck in the sand, so that you may be able to borrow away your slings; but if you find the stones to bury themselves, you will save expense by procuring old cordage to make them of.

On supposition that the stones in still weather do not bury themselves, if you can at low water give them some assistance it may not be amiss; but at any event, the piling a weight of stones upon them will, with the aid of the action of the sea, cause them to settle, and at last to ground themselves.

Supposing this to be an operation that would occasion the foundation to go on for more than one year, the best way would be to carry on the work progressively from the rocks towards the head, as by that means every part would have time to ground, while the part beyond it was advancing; but as the whole at least of the basement is expected to be completed in one season, to give it all the chance possible of storms to make it ground, I am of opinion, that you should begin with the head, and go on to complete the rough basement between the head and the rocks, so as to bring the whole to a level about one foot above low water, and then go on with the upper works (the outsides of which are to be of scappeled blocks) to proceed progressively from the rocks towards the head, for by this means the head, whose firm establishment is of the principal consequence, will have the greatest share of time to come to a firm bearing; and when you cannot on account of the tide work below, you may be employing the people in getting the work forward that is upon the rocks.

Your

Your first work will be during the winter to provide all the large rough pieces of rock you can procure, in order to make the rough basement, and as far as may be convenient to get them brought to the place.

In regard to the masonry of the upper works, as the turning of the head cannot be done otherwise than with stones upon their flat beds; and as I never intended this interior pier to be built otherwise than with the stones upon their beds, the distance between the head and the rock will be so short, that it will be hardly worth while to change the masonry; however, if you find any convenience in the diagonal way of working for the outside, you are at liberty to put it in practice.

The whole I propose to be built dry till you come to lay on the platform or top of the pier, after which you will proceed with mortar as usual. As the joints of the stones in turning the head of the pier will be radii, or pointed to the centre, and will have nothing naturally to retain them from getting outward but their own weight and the incumbent weight of the matter above, it will be proper to cramp them every third course, or otherwise to retain them to the more central parts by iron doggs. And by way of securing the platform or cap of the pier head, which will be the most apt of any other to get loose, and at the same time to make it a firm tie upon what is below, I propose the work thereof to be jointed dove-tail-wise in the Edystone fashion, as shewn in the additional design, *Fig.* 7. Plate 5.

If you find it adviseable by way of tying your work faster together to begin with mortar above high water, for some of the last courses next the platform, and can procure lime with pozzelana, I shall have no objection; but if this will embarrass the work, I do not hold it to be absolutely necessary.

Austhorpe
6th *January* 1774.

J. SMEATON.

N. B. As the high and low water lines are not certain determinate heights, you are to be guided by the pier already done; the cap or platform of the flank pier, and the top of its parapet, being respectively of the same height as the present pier.

RAMSGATE HARBOUR.

(See the Plan, Plate 7.)

An Hiſtorical REPORT on Ramſgate Harbour, wrote by order of and addreſſed to the Truſtees, by JOHN SMEATON, Civil Engineer, F.R.S. and Engineer to Ramſgate Harbour, 1791.

To the Truſtees of Ramſgate Harbour.

SIRS,

THE following piece was begun laſt year by your order, principally with a view to inform the public of the improved ſtate of Ramſgate Harbour, and of the Improvements that were in a way to be further brought about; as alſo of the unexpected difficulties that had occurred in the progreſs and actual execution of this long deſired eſtabliſhment.—Indeed the ſmall length of time that it had been a Harbour, capable of fulfilling the purpoſes for which it was begun, had ſcarcely given opportunity to the maritime part of this Nation, and more eſpecially to foreigners, to acquaint themſelves with the advantages they might derive from the uſe thereof.

It is now ſomewhat more than ten years ſince Ramſgate Harbour was ſo far cleanſed of ſand and ſilt, as to be capable of taking in ſhips of ſuperior draught of water and tonnage, to what appears to have been the object of Parliament in granting the act, as well as to the views of the original promoters of the undertaking; yet it was not till the winter before the preſent (January 1790), that the real practical utility of this Harbour appeared in full view, for it had ſo happened, that the ſame means that had been neceſſarily employed for cleanſing it, (that is to ſay, for conſtituting it a Harbour), had ſubjected it to that kind of agitation and inquietude, which in general rendered it more eligible for veſſels of burden, ſuch as might very well have come in as to draught of water, to ſubject themſelves to the wear and tear of their tackle, and the riſk of riding it out in the Downs, than come into the Harbour till they had received ſome actual damage.

The quietude of the Harbour has at length in a great meaſure been happily effected, along with the other advantages, by the progreſs made in the conſtruction of an advanced pier. This was only begun in the ſummer of 1788, and at Chriſtmas 1789 was run out the length of 120 feet, that is nearly one third of its propoſed length; which ſo ſenſibly

ſenſibly quieted the Harbour, that in January and part of February 1790, there were in it no leſs than 160 ſhips and veſſels that came in for refuge, and to ſave the wear and tear of their tackle and furniture, all of which muſt otherwiſe have crowded the Downs.—Almoſt an equal number, for the ſame reaſon, came into the Harbour during the tempeſtuous weather of the paſt January.

It may however poſſibly ſeem to ſome, that the means now taking to quiet the Harbour may operate to render it leſs acceſſible: but this, when properly underſtood, will not appear to be the caſe, but ſo far otherwiſe, that in reality a ſhip will come in with greater facility; for the Harbour's mouth is in effect as wide as it was before the advanced pier was begun.—The original width of the Harbour's mouth, as intended, was 200 feet; the opening to be at S. S. W. The width ultimately fixed by the Truſtees was 300 feet at S. ½ E. but that width and poſition appear to have been ſettled at a time when the Truſtees were apprehenſive of the Harbour entirely choaking up with ſilt, if more incloſed, and not from any neceſſity of that width, merely for the ſake of facility of entry; 200 feet clear opening being deemed a large ſufficiency for the entry of an artificial Harbour, entirely raiſed out of the ſea by the hand of man.

When the Harbour was formed, it was found that during all the time of full ſea, a ſtrong current ſets almoſt right acroſs the Harbour's mouth, that is, from weſt to eaſt, which being a natural cauſe, cannot be diverted; a veſſel therefore coming from the ſouth, that is, from the Downs, were ſhe to attempt to run into the Harbour, right acroſs the current, would be carried eaſtward thereof, ſo as to miſs it: it has therefore been an eſtabliſhed maxim, ever ſince the Harbour was formed, and given out as a direction, for veſſels to come in obliquely from the weſtward, and as cloſe as properly may be to the weſt pier head; and this courſe, as marked out many years ago upon the plans of direction, will carry a veſſel right through the preſent intended opening, betwixt the weſt head and the head of the advanced pier, which is full 200 feet in width, and ſhe will always come in with the tide in her favour.

In conſequence of your orders, in the courſe of laſt ſummer I made a conſiderable progreſs with this Report, intending to have completed it at leiſure this ſpring, but if by being called upon more haſtily than I had expected, it comes out leſs finiſhed than I could have wiſhed it, I have this only circumſtance to plead in my excuſe.

I remain, Sirs, &c.

J. SMEATON.

SECTION I.

ACCOUNT of early attempts towards a Harbour for the Downs, and of proceedings, incluſive of obtaining an Act of Parliament, for eſtabliſhing a Harbour for that purpoſe at Ramſgate.

THE expediency of a Harbour for the reception of Ships in the Downs, has doubtleſs ſubſiſted as far back as the increaſe of our trade and ſhipping has rendered it important; but the want of a ſituation ſtrongly pointed out by nature, was probably the reaſon why we have not heard of any attempt towards it in the earlieſt ages.

In the time of King Edward 6th it is ſaid there was an attempt to make a Harbour from Sandwich into the Downs, and that the evident traces of a canal, which ſtill ſubſiſt in the level grounds, between Sandwich and Sandown Caſtle, are the remains of that attempt. It is alſo ſaid, that commiſſioners were appointed by Queen Elizabeth in 1574, for taking a ſurvey of Sandwich Haven, and to give their opinion as to the making a better Harbour near Sandown Caſtle. Alſo that in 1706, a plan, report, and eſtimate, were delivered by perſons appointed to ſurvey and eſtimate the expenſe of a new Harbour from Sandwich into the Downs, accompanied with a certificate of the Flag Officers, and many commanders of the ſhips of her Majeſty's royal navy, who then gave it as their opinion, that ſuch a Harbour might be of general advantage to the public.

It ſeems alſo that petitions were preſented to the Honourable Houſe of Commons, praying for a new Harbour near the Downs, April 2d 1736; and that a committee appointed by the Houſe heard evidence upon the matter thereof; and that in conſequence a plan and ſurvey of the Downs and coaſts adjoining, were undertaken by Mr. Labelye, afterwards Engineer to Weſtminſter Bridge, at the expenſe of Sir George Oxenden Baronet and Joſiah Burchett Eſquire, then members for the town and port of Sandwich; a copper plate of which was publiſhed in 1737-8, in which he exhibits a ſcheme for ſheltering ſhips from the Downs by a navigable canal and baſon, in the very direction of the Old Cut above mentioned, and by ſluices to join the river Stour.

In April 1744, the Houſe of Commons preſented an addreſs to the King, "that he would give directions to proper and ſkilful perſons, to view the Haven of Sandwich, and examine whether a better and more commodious harbour may not be made into the Downs near Sandown Caſtle, fit for the reception and ſecurity of large merchant ſhips and men of war; and to ſurvey the ſaid ground and ſhore; and alſo the river Stour, neceſ-

ſary

ſary to cleaning and ſcouring the ſaid Harbour when made; and to make an eſtimate of the charges and expenſes thereof;" to be laid before Parliament the enſuing ſeſſion.

In conſequence of the above, an order was iſſued from the Admiralty, appointing the following perſons to this buſineſs; W. Whorwood, John Redman, John Major, Thomas Slade, Charles Labelye, and R. Charles; who reported, that having made the neceſſary obſervations, "a better and more commodious Harbour, than the preſent haven of Sandwich, may be made from the town of Sandwich into the Downs near Sandown Caſtle."

They propoſed to carry out two ſtone piers, each 2,096 feet in length from the ſhore, into twelve feet depth of water at low water; to have a clear opening between the heads of 300 feet; to narrow from that to 100 feet; and that the middle line ſhould point S. S. E. ½ E. by the compaſs; that is nearly S. E. by the true meridian, or S. S. E. as the compaſs now points. The eſtimate for this work was £.389,168. 13*s*. 2*d*. excluſive of the value of the grounds to be purchaſed.

The report being referred to a committee of the whole Houſe of Commons; after examining evidence of pilots and perſons beſt ſkilled in the navigation of the Downs, the committee came to a reſolution, dated the 26th February 1744-5, importing, that it appeared to them, "that a ſafe and commodious Harbour may be made into the Downs near Sandown Caſtle, fit for the reception and ſecurity of large merchant-men and ſhips of war of ſixty and ſeventy guns, and be of great uſe and advantage to the naval power of Great Britain.

Why this great work was ſuſpended, after being brought this length, does not now diſtinctly appear; but if we conſider the largeneſs of the ſum eſtimated, for a work ſuppoſed to be undertaken by Government, at a time when we were at war with France and Spain, we perhaps need not be at a loſs to judge.

The whole affair ſeems however to have lain dormant for ſome time, till the public was rouſed by a violent ſtorm which happened on the 16th December 1748, wherein a great number of veſſels were driven from their anchors in the Downs, and being forced upon the ſouth coaſt of the Iſle of Thanet, ſeveral found ſafety in the little harbour of Ramſgate.

This

This ſeems at once to have opened the eyes of the public, and cauſed them to be turned upon Ramſgate as the proper place for the reception of ſhips when in diſtreſs from bad weather in the Downs; and accordingly, the 8th February following, a petition was preſented to the Houſe of Commons, by ſeveral merchants of the city of London, owners and maſters of ſhips, whoſe names were thereunto ſubſcribed, amounting to 131, which was referred to a committee appointed to ſit the 13th following; and on this day a petition was preſented from the mayor, magiſtrates, freemen and inhabitants of Sandwich; ſetting forth the damage that would be likely to ariſe to the haven and port of Sandwich from the extenſion of piers into the ſea at Ramſgate, which was referred to the ſame Committee.

In ſupport of the Petition of the merchants, owners, and maſters of ſhips, a great number of witneſſes were examined, and to a conſiderable length: and the following points were fully and clearly proved, to the ſatisfaction of the Committee.

1ſt. That, in the ſaid great ſtorm of December preceding, a number of ſhips were actually forced into, and ſaved in Ramſgate Harbour, although then ſo ſmall as to be ſcarcely capable of receiving veſſels of 200 tons, at any time of tide; that pier having been only built and maintained by the fiſhermen of the place.

2d. That the winds in the Downs, whereby ſhips riding there are moſt apt to be annoyed, are from S. S. E. to S. S. W.

3d. That at Ramſgate, or near it, was not only the beſt, but in reality the only place, where any harbour could be built, that could be ſerviceable to ſhips in diſtreſs in the Downs, becauſe Ramſgate was right in the lee of that road, with ſuch winds as produced that diſtreſs; and at ſuch a proper diſtance, that, after driving or breaking looſe, they had time to get under ſail, ſo that with a ſlender ſhare of ſeamanſhip they could make a harbour if built there.

4th. That though this ſhore was univerſally flat, yet as it gradually increaſes in depth from the Cliffs towards the Downs, it was practicable, at a moderate expenſe, to carry out piers into ſix feet and a half water, at the low water of a middling ſpring tide; and that, according to the riſe of the tides, there would be water enough from three-quarter flood to one quarter ebb even at neap tides, to carry in veſſels drawing fifteen feet water, which, if full built, was ſuppoſed to be full 300 tons burthen.*

* I underſtand it can be made to appear that more than two-thirds of all the tonnage and value of ſhipping is carried on in veſſels not exceeding 300 tons.

5th. That

5th. That when veſſels break looſe from their anchors in the Downs it is generally from three-quarter flood to one-quarter ebb,* during all which time the courſe of the current of the tide is to the North and N. E. which therefore would carry them right into a harbour at Ramſgate, ſo that by the time they got thither, it would be within an hour of high water.

6th. That the ſoil at Ramſgate being a chalk ſufficiently firm to build upon, but yet ſo yielding that the keels of veſſels readily make a dock for themſelves therein; this, with ſometimes a ſlight cover of ſand, forms a proper bottom to lay full built ſhips aground upon at low-water; and even if ſharp built, will, in caſe of neceſſity, ſubject them to the leaſt poſſible damage; and indeed to little or none, if proper precaution be taken to lay them againſt a pier; nor can they ſuffer in the leaſt, if a proper baſon be conſtructed to lay them afloat.

7th. That in time of war merchant ſhips are built ſharper than in time of peace; but that at an average more of the London traders are built full than ſharp.

8th. That the great ſhips in the Downs are obliged to ride in a bad road to be out of the way of the ſmall veſſels, which commonly lie in the ſmall Downs, and thoſe ſmall veſſels being often ill-furniſhed with anchors and cables, frequently break looſe, and drive upon the large ſhips, which then run foul of each other; whereby ſometimes a whole fleet is ſet adrift; and in the opinion of Captain Conway (then an elder brother of the Trinity Houſe) if a harbour were only made for the reception of ſhips of 200 tons and under, it would prevent nine-tenths of the damage that happens in the Downs; as he ſuppoſes all ſhips under 200 tons, waiting for a wind to proceed weſtward, would take ſhelter therein.

9th. That ſhips in Ramſgate Harbour may ſail out of it with any wind, that would carry them weſtward out of the Downs; and even with a ſtrong wind at eaſt, or with a ſcant wind at S. E. by E. they can make good their courſe out of Ramſgate Harbour, by virtue

* This will appear clearly to be the caſe, when it is conſidered that they are the Goodwin Sands that conſtitute the Downs to be a road for ſhips. At low water thoſe ſands may be conſidered as a pier or break-water to all the eaſterly winds; and even at high water, it is too ſhallow over them to admit the great ſeas to paſs, without being much broken and diſperſed, eſpecially in ſtormy weather. From the ſituation therefore of the Downs, theſe ſands on one ſide, and the coaſt of Kent on the other, it is only the ſoutherly winds that can annoy them, which alſo are much moderated by the proximity of the coaſt of France; and ſtill more ſo, by the firſt part of the flood tide running ſouthward, and meeting the ſeas; it is therefore not till the tide turns to the north (which is at or about three-quarter flood) that the combined force of wind and tide, makes the great effort to break the ſhips from their moorings.

of the flood tide, under their lee, and fail weftward, when fhips in the Downs cannot purchafe their anchors.

10th. That large craft might be conftantly kept afloat in Ramfgate Harbour, at low water, fuch as might be able to carry out pilots, anchors, cables, and other affiftance to men of war and large fhips in diftrefs in the Downs;* and the matter is fo circumftanced that whenever they could not go from Ramfgate, boats may go out from Dover to fhips in the Downs.

Upon this evidence, which I have carefully extracted from the Committee's report, I only beg leave to obferve; that the tides, the fands, and the coafts remaining the fame, as alfo the natural powers, what was true in the year 1749 will remain true in the year 1791.

During the whole of this inveftigation the great project of a harbour at Sandown Caftle feems to have been altogether loft fight of; and perhaps at this we may the lefs marvel; if cafting our eye upon the pofition thereof; veffels breaking loofe from their anchors there, with wind at any point from S. S. E. to S. S. W. would be driven to the leeward of the harbour's mouth before they could get under way, fo as to be under dominion of their helm; and therefore, after all, liable to be wrecked or run afhore upon the fouth coaft of the ifle of Thanet †.

Nor indeed, according to my judgement, could a more injudicious conftruction than the piers propofed at Sandown, be well imagined; for the heavy feas that would fall in between the heads (that is, all thofe producing diftrefs in the Downs) would be fo augmented by the gradual contraction of the diftance of the piers, from 300 feet at their entry, to 100 feet near the bafon; that veffels would not only be liable to be wrecked between the piers, but thofe augmented feas would infallibly deftroy the gates of the bafon; and

* Such crafts and pilots now actually ftation themfelves at Ramfgate, and are the means of faving many lives and much property.

† While the inveftigation for a harbour at Sandown Caftle was going on before Parliament in 1744, reafons were offered againft making a harbour near Sandwich; to which at that time no regard feems to have been paid, viz. Sandwich having no convenient outlet for fhips bound to the weftward, they muft remain wind-bound with many fair winds. 2dly. The inlet is inconvenient to receive fhips bound to the weftward, which are detained in the Downs by contrary winds and ftormy weather; for if any fhip's anchor ftart, or cables give way, they muft drive paft the harbour, before the fhip can be brought into a pofition to put for the entrance.

probably

probably the fixed part of the ftone work alfo.—It hence appears moft evident, that nature has not in reality furnifhed any fituation for a harbour for the Downs preferable to that at Ramfgate; and therefore we need not wonder, that the project of the long-wifhed for harbour for the Downs was at that time promoted to be at Ramfgate, with a degree of eagernefs and even of enthufiafm.

The Act paffed that feffion, fetting forth in its preamble, " Whereas frequent loffes of the lives and properties of his Majefty's fubjects happen in the Downs for want of a harbour between the North and South Forelands; the greateft part of the fhips employed in the trade of the nation being under a neceffity at going out upon as well as returning from their voyages, to pafs through the Downs; and frequently by contrary winds being detained there a long time; during which they (efpecially the outward-bound fhips) are expofed to violent ftorms and dangerous gales of wind, without having a fufficient harbour to lie in or retreat into, or from whence they can receive any affiftance: And whereas a harbour may be made at the town of Ramfgate proper and convenient for the reception of fhips of and under 300 tons burthen; and from thence larger fhips in diftrefs in the Downs may be fupplied with pilots, anchors, cables, and other affiftance and neceffaries; and by the fmaller fhips taking fhelter in this harbour the larger fhips may take the anchorage which at prefent is occupied by the fmaller, and by that means their anchors will be fixed in more holding ground, and the fhips not fo expofed to the ocean; for carrying therefore a work of fuch public utility into execution, &c. be it enacted," &c.

The firft meeting of the truftees was appointed at the Guildhall London the firft Tuefday in July 1749, (that was then next following), at which a large number named in the Act, to the amount of fixty-fix, appeared to qualify.

SECTION II.

PROCEEDINGS of the Truftees from the Commencement of the Work in 1749, to the total Stoppage of the fame in 1755; upon Petition to the Houfe of Commons.

THE firft act of the truftees regarding conftruction was to appoint a Committee of their body to view the place at Ramfgate, where a new harbour was intended to be made; and report their obfervations and opinions to the truftees at their next meeting; and

and that Mr. Robins and Mr. Turner of Gosport should be desired to attend them as engineers.*

The Committee accordingly met at Ramsgate, and on their return, reported, that in consequence of objections having been made before the Committees of the House of Commons to Ramsgate, for want of a back-water, they having examined found from information, that in the year 1715 the pier then standing had been lengthened; and by inspection it appeared, that a bar of about forty yards breadth and length had been cast up, its highest part in thickness two feet and a half; and they considering this small quantity as the gradual effect of 34 years, thought it reasonable to expect, that when a greater depth of water was made by two piers instead of one, the filling up by sullage or beach would become so inconsiderable, that a small expense would continually prevent its increase.

They further observed, that the seaweed or sullage that drove in, came from the westward; and that from the east there was a drift of large shingle; which if it should take place, would be of advantage in backing the new piers. They also made and reported many other observations confirming what was given in evidence before the House of Commons in its favour.

They endeavoured to fix their opinions as to one material point, which could not be so conveniently settled in evidence before the House; and about which there was some diversity of opinion; and that was the position of the harbour's mouth, whether South, S. S. W. or S. W. were to be preferred. Towards the resolution of which question the committee premised, "that the stream of the tide in the Downs sets for six hours to the northward, or at least between the north and the east, and then for the next six hours the stream turns and sets to the southward, or between the south and the west; but the time of high and low water does not correspond to the beginning and end of these streams; for it is high water about two hours after the stream has begun to run to the northward; and it is low water two hours after the stream has set to the southward, so that when the tide first sets to the northward, more than two thirds of the tide has flowed; and high water happens about two hours after:" and that having separately examined eleven captains or masters of ships of Ramsgate, they all unanimously agreed, that the most dangerous winds in the

* It may at this day seem extraordinary, why Mr. Labelye, who appears to have made the original plan, upon which himself and associates proceeded as mentioned above, should not have been called upon and consulted in this latter stage of the business; but if it be remembered that in the year 1748, one of the piers of the new bridge of Westminster, built under his direction, most unfortunately settled, so as to oblige two of the arches to be taken down, after the bridge had been opened to the public, we may be the less surprised.

Downs

Downs were from the S. S. E. to S. S. W.; and that the time when ships run the greatest risk of being forced from their anchors, is when the northward stream sets in; and that about the same time, that is the beginning of the northern stream, was likewise the most prudent for such ships as should intend to make for Ramsgate harbour, to slip their cables; for, that in either case, they would have both wind and tide in their favour, in standing for Ramsgate; and that on their arrival, they would find it near high water, allowing an hour for their passage: and they unanimously agreed, that an entrance to S. S. W. was to be preferred: for if placed full south, the tide near high water would run so strong across it, as to render it difficult to get in; and if at south-west, they feared there might be too great an indraught of sullage. All the bearings then referred to were settled by the compass, which in the Downs was then $1\frac{1}{2}$ point west.

They also particularly attended to the point, whether the piers should be built with wood or stone; but agreed unanimously stone was greatly to be preferred, had it not been for the great difference of expense, especially as they had found (and brought up specimens) that the worm bit considerably in the pier then standing. On the whole they were satisfied, a harbour at Ramsgate would be as practicable, useful, and important, as they had before thought; and concluded with observing, that no other motive than that of avoiding expense should have any weight in assigning to this harbour a form less perfect or extensive than it was by nature capable of receiving. It does not, however, appear that the Committee, on this occasion, were attended by Mr. Robins or Mr. Turner.

The next step of the trustees was to advertise to invite engineers to deliver plans sealed up, to their secretary Mr. Elliot, for piers of stone or of wood, with the necessary specifications, and explanations, against the 29th September following.

At this time, several plans and models were offered, and the 19th October appointed for taking the plans into consideration: and also the secretary was ordered to invite engineers, or gentlemen acquainted with engineery, to assist the trustees upon that occasion. Accordingly, upon the 19th several persons attended under that description, and were desired to appoint a meeting among themselves to consider the several plans, and give their opinion to the trustees; and the secretary was ordered to invite the gentlemen who should attend to dinner, at the expense of the trust.

On the 26th of October the engineers delivered their report, which was subscribed by Benjamin Robins, Thomas Innes, J. Leake, John Muller, and John Turner. The most material things that occurred therein were:

That

That it was improper to lay the foundation of the piers below low water mark, with looſe ſtones thrown in at random.

That if the piers were not carried out into a greater depth of water than 6¼ feet, at low water of ſpring tides, it did not appear neceſſary to be at the expence of carrying on the foundation by caiſſons.

That the propereſt method of laying the foundation of the intended piers in the parts covered at low water, was by making a baſement of ſtone ſomewhat higher than low water mark, after the manner propoſed by Mr. Turner.

At a ſubſequent meeting, Mr. Deſmaretz, Mr. Prat, and Mr. Mill, gave their opinions relative to the manner and materials neceſſary for the building the piers of the intended harbour.

The truſtees then ordered notice of a meeting upon the 15th December, for taking into their conſideration all the plans and propoſals that had been or ſhould be laid before them, and to come to a determination thereon: and that all perſons having any thing further to offer, ſhould be deſired to deliver in their propoſals before that time; recommending a full meeting of the truſtees on this extraordinary occaſion.

At this meeting ſeveral plans and ſections were examined, amongſt which was a plan from Captain Robert Brooke of Margate, and a ſection from Mr. Deſmaretz chief engineer at Portſmouth; and at a ſubſequent meeting, three more plans and ſections were delivered, amongſt which was a plan and ſection by William Ockenden Eſquire, one of the truſtees: and at a meeting after that, ten different plans, laid before the board in conſequence of the original advertiſement, were examined; and an abſtract ordered to be made by the ſecretary, and laid before the next meeting; at which, on the 12th January 1749-50, it was reſolved, that the harbour ſhould be proceeded with according to the plan ſigned by the chairman, ſubject to the further alterations of the board. That the eaſt pier ſhould be proceeded upon with ſtone; and the weſt pier with wood.

At a ſubſequent meeting it was reſolved, that the plan and ſection propoſed and delivered by William Ockenden Eſquire, for erecting a ſtone pier, ſhould be the method of building the eaſt pier; and that the ſection and model which was propoſed and delivered for a wooden pier by Captain Robert Brooke, ſhould be the method of building the weſt pier to low water mark neap tides: and that Mr. Ockenden and Captain Brooke ſhould be applied to, for their deſcription of the proper materials for the piers reſpectively propoſed by them.

The

The 2d February 1749-50, it was reſolved, that the eaſt pier ſhould be carried on by workmen appointed by the truſt, and materials purchaſed for 100 feet of pier; and Thomas Preſton was appointed maſon or foreman of the ſtone work; who by the Board's order, ſet out for Maidſtone, Folkſtone, Dover, and Ramſgate; and was to follow the inſtructions given him; and Captains Conway, Stevens, and Bennet, were deſired to aſſiſt Captain Brooke in purchaſing materials and carrying on the weſt head.

Mr. Preſton's firſt report of the 23d following, chiefly contained an account of the ſtone materials afforded, and uſed at the places ſpecified; whereupon he was ordered to go to Purbeck, to make the proper enquiries concerning the ſtone there: Mr. Ockenden, Sir Peter Thompſon, Mr. Fry, Captain Barker, Captain Hughes, Mr. Hyde, Mr. Norris, and Mr. Pole, were appointed a committee for carrying on the eaſt head, and were deſired to confer with the committee for the weſt head, as often as they ſhould find neceſſary. Mr. John Scott was appointed foreman for carrying on the weſt pier.

Things being thus ſettled, nothing happened but what might be expected to be the reſult of the diſpoſitions mentioned; and it is worthy of notice, that a quantity of Barrow limeſtone was got, as recommended by Mr. Preſton.

In 1751, a committee being appointed by the board to make a ſurvey of the ſtate of the works, made their report the 25th July. The moſt material things to be obſerved were as follows:—

That the ſtone pier extended 390 feet, of which 104 feet were completely ready for the parapet, and the reſt above the reach of a ſpring tide; and that while the committee was there, the foundation was run on 83 feet further, in the whole 473 feet. They examined the work, and found it free from any kind of failure whatever.

The weſt head was carried out about 460 feet from the cliff; and 540 feet thereof were propoſed to be completed that year.

The commitee were attended by Mr. Turner of Goſport and Mr. Vincent of Scarborough, and recommended the uſe of aſhler inſtead of backing ſtone, ſince a cube foot of ſhell lime * coſt more than a cube foot of aſhler.

A locker or grind was then recommended, the committee being of opinion it would collect the ſand and ſhingle in the outward angle of the eaſt pier with the land.

* At this time ſhell lime was uſed for the backing of Ramſgate harbour.

By

By the ſeparate report of the engineers, of the ſame date with that of the committee, it appears they were of opinion, that the part of the ſtone pier then done, was but barely ſufficient to reſiſt the force of the ſea; therefore recommended the future parts to be made with 40 feet baſe, and 30 feet at top; and an additional courſe of aſhler, to the height of 18 feet above the foundation, both inſide and outſide; and above that, one courſe only; the core to be leſſened. The chalk to be well beaten, and mixed with gravel; and not mixed with mortar as then practiſed. All the aſhler to be ſet with terras mortar, and the backing mortar made with brick-duſt or ſea-coal aſhes.

In ſurveying, they found the bottom regular, and in the circumference of the harbour, the depth of low water not exceeding five feet ſix inches; and that the foundation might be carried out without caiſſons, ſo as to anſwer the deſign, in a manner by them deſcribed; which was that of laying large Portland blocks in the ground courſes, ſo as to reach above low water.

The following Board agreed to the uſe of aſhler for backing, for the reaſons given by the committee in their report. A locker or grind to be made as propoſed. Captain William Read was appointed haven-maſter, with inſtructions to hoiſt a flag when there was ten feet water at the old pier head.

6th December 1751, a general meeting was appointed to conſider of the method of founding the piers beyond low water mark, when Mr. William Etheridge produced a model of a caiſſon; and a model of a tool, and method of working it, for making a trench, and levelling the ground under water for ſetting the caiſſon upon. Captain Robert Brooke ſent a model for laying the foundations of ſtone, without caiſſons, accompanied with a deſcription. In conſequence of which the truſtees ordered an advertiſement for contractors to deliver plans, propoſals, and eſtimates, for conſtructing the piers beyond low water mark.

The 3d January 1752, Mr. James Morehouſe preſented a plan, propoſals, and eſtimates; which however were not approved; but it was reſolved, that a foundation, not exceeding 200 feet, ſhould be carried on with large blocks of ſtone, agreeably to two plans given in by Mr. Preſton the maſon.

24th January; it was reſolved that the ſaid 200 feet of ſtone pier ſhould have its foundation laid in a channel or trench, dug into the chalk ten or twelve inches deep; and a motion was made, and agreed to, that a ſurveyor ſhould be appointed; and that a proper advertiſement

advertiſement ſhould be conſidered for the purpoſe: Friday the 21ſt was appointed for the election of one, from ſuch perſons as ſhould offer, to inſpect and direct the careful and expeditious carrying on of the building; and the maſon's report was poſtponed till a ſurveyor ſhould be choſen; but Boulogne lime and lime kilns were ordered to be ſet about immediately.

21ſt January. It was reſolved that ſuch ſurveyor as ſhould be choſen, ſhould have a ſalary of £200. per annum, and reſide at Ramſgate.

On this occaſion, ſeven perſons applied; amongſt whom were Mr. Etheridge, and Mr. Vincent the Engineer of Scarborough Pier, who both produced ample teſtimonials; but on holding up of the hands, the majority was declared for Mr. Etheridge, who was ſtrongly recommended by Mr. Ockenden, and who received on this occaſion the thanks of the Board for his plan, care, and attention; and which were deſired to be continued.

28th February. Inſtructions were given by the truſtees to the ſurveyor, and were in ſubſtance as follows:—

"The ſurveyor is to reſide in Ramſgate, and not be abſent without leave firſt obtained from the truſtees at one of their meetings; and to have the inſpecting and directing of all the works that have already or ſhall be hereafter carried on, under the direction of the truſtees of Ramſgate Harbour; and alſo to have the direction of all the perſons employed therein, at Ramſgate, except the clerk of the cheque. He is weekly to tranſmit to the ſecretary an account of the progreſs of the work, and of the tranſactions relative thereto, that they may be laid before the Board at their ſeveral meetings. He is truly and faithfully to inſpect the ſeveral materials which ſhall be delivered, and report to the Board thoſe which are not according to agreement or contract; and frequently to examine the liſt of the workmen employed, and ſee that they perform the labour they are paid for; and as ſoon as he conveniently can, he is to take an account of the abilities of the ſeveral workmen employed, and report to the ſecretary, whether they are deſerving the wages therein charged; but no alteration of wages ſhall at any time be made by him, without firſt mentioning his intention to the truſtees, and receiving their approbation. The increaſing or leſſening the number of workmen to be left to his diſcretion. But he is from time to time to acquaint the Board of his reaſons for whatever alterations he ſhall make among them. Nor is he to make any material alteration of any kind, without previouſly acquainting the ſecretary thereof, and taking the directions of the truſtees thereon. In general he is to inſpect and direct every thing relating to the works, ſo that they may be carried on in the moſt expeditious and frugal manner."

25th

25th March. Mr. Etheridge delivered his first report, which describes the state of the works at Ramsgate on a general view; and having inspected a cargo of backing stone brought from Purbeck, he thought it very good, and capable of making very sufficient work, without building the wall entirely with ashler; but for the benefit of the work, he recommended to send a proper person to Purbeck, at the expense of the trust, to see that the stone be good, properly worked, and the courses shipped as wanted; which was afterwards ordered by the Board.

Here it may be necessary to observe, that Mr. Etheridge appears to have been a person of a truly mechanic genius, and having been brought forward by the celebrated Mr. King, carpenter of the works of Westminster Bridge, as his foreman, and after Mr. King's death become his successor in completing this branch of those works, might be presumed to be a man of much experience in the carpentry line:* but being here appointed director of the whole work, and looking upon himself as competent to the masonry as to the carpentry branch, there very soon arose a difference of opinion betwixt the surveyor and Mr. Preston the mason, that afterwards turned out of great detriment to these works. Mr. Preston, though by no means equal to Mr. Etheridge in general mechanical knowledge, yet was an excellent mason, and well informed in the nature of the materials proper to his trade:—the making of mortar being rather of a chemical than a mechanical nature. Mr. Preston, before the appointment of Mr. Etheridge, not being satisfied with the use of shell lime under water, which was in part used at Ramsgate Harbour, recommended to the trustees the trial of various lime stones; viz. Aberthaw, Barrow, and that of Boulogne, of which cargoes had been ordered; but their merits had not then been sufficiently investigated. Mr. Etheridge unfortunately had adopted shell lime for waterworks, and accounted that of Maidstone, and St. Vincent's Rocks at Bristol Hot Wells, as preferable to the above. †

Mr. Etheridge, as reported, being of an austere temper, not readily giving up what he had once advanced, a shyness took place between these two officers; which though it did not prevent either of them from punctually doing his duty, that is, did not prevent Mr. Preston from scrupulously pursuing his orders from Mr. Etheridge; yet it prevented that interchange of sentiments and confidence, which is so essentially necessary among the principal officers of a great work or enterprize, that it may be carried on to the best advantage.

* Mr. Etheridge afterwards designed and built the famous wooden bridge at Walton-upon-Thames; the middle arch of which spanned 120 feet.

† See the chapter on water cements, Smeaton's account of Edystone lighthouse.

Mr.

Mr. Etheridge now proceeded to put in practice his proposed method of laying the foundation of the piers, in cases or caissons, and shewed that method of digging a trench under water, and levelling it, which, being attended with certainty, and every necessary degree of dispatch, has ever since been the method put in practice here, and so continues to this day.

Every thing appeared to go successfully on during the year 1752; and the committee of the 29th September, reported that 68 feet of stone pier, of the same dimensions as the east pier, had been added to the 550 feet of timber work of the west pier, and 138 feet of foundation carried out five feet high.

The 26th January 1753, produced an order of Board, that Mr. Ockenden, and any other gentlemen of the trust, should be desired to go to Ramsgate to consult with the surveyor there, and give directions for a proper plan to be drawn of the extent and manner in which the work should be carried on and finished; and that the said plan should be laid before the Board for approbation.

14th May 1753, the Board read Mr. Ockenden's report of his survey made at Ramsgate, and considered the plan for carrying out the work, which is dated the 21st April, and signed by him and the surveyor, but came to no resolution thereon; however Mr. Ockenden received the thanks of the Board, for his great care and pains in making his late survey and report.

At a general meeting, 14th December 1753, for considering the plan of the Harbour, a motion was made, that the Harbour be contracted to 1,200 feet in width, according to the plan this day laid before the Board by Mr. Ockenden; which, being debated, was carried on a division of 28 to 15. And on an adjournment to that day se'nnight, the resolution was confirmed; 26 to 7.

Upon this contracted plan, which appears to have originated with Mr. Ockenden, Mr. Etheridge seems not only to have vigorously proceeded, but even to have pushed the execution; for, by the Committee's report on their visitation, the 9th October 1754, after declaring their opinion, that the contraction ordered by the Board would leave the Harbour large enough to contain more ships than would ever have occasion to lie there, at the same time; and "that the curve at the west pier continuing the same as it was in the original plan, would give sufficient room for ships to bring up;" they reported, that at the west pier, the 138 feet of foundation mentioned last year to be laid, was taken up, and a temporary

rary croſs wall of backing ſtone had been carried out eaſtward 278 feet; but that from the eaſt end of this, nearly 300 feet had been carried out ſoutherly, to five feet high and upwards; and 111 feet to 19 feet 8 inches; and furthermore, that the piles had been driven for founding 80 feet more.

At this meeting the ſurveyor pointed out a communication to be neceſſary by land to the weſt pier at high water, and recommended a ſtair-caſe from the top to the bottom of the cliff; which work being ſoon after executed, was called Jacob's Ladder, which name it ſtill retains.

This appears to be the laſt work of Mr. Etheridge at Ramſgate, for while the works of this ſummer were going on, remonſtrances to the truſtees came from ſeveral ports, declaring ſtrongly againſt the contraction, and which ended in an application to Parliament in 1755; when the petition of merchants, owners, and maſters of ſhips, whoſe names were ſubſcribed, ſet forth; "That from the works carried on under the direction of the Truſtees of Ramſgate Harbour, for ſome time the petitioners had great reaſon to hope, that a ſafe and commodious Harbour would be made there, for the reception of ſhips and veſſels; and thereby the intention of the Legiſlature anſwered in impoſing the duties; but that, in or about December 1753, the ſaid Truſtees had reſolved to alter and contract the ſaid Harbour; and during the laſt ſummer, ſuch works had been carried on towards altering and contracting the ſame, that if further proceeded in, and finiſhed according to the ſaid reſolution of the ſaid truſtees, would, in the petitioners' apprehenſion, render the ſaid Harbour in a great meaſure uſeleſs; and that the expenſe thereof would be loſt to the public."

"That as the petitioners were fully convinced a ſafe, commodious, and uſeful Harbour might be made at Ramſgate, to the great advantage of the commerce of this kingdom, under ſkilful and proper directions;

"The petitioners therefore humbly prayed the honourable Houſe to take into their conſideration this matter, in which the public was ſo greatly intereſted, and grant ſuch relief therein, as to the honourable Houſe ſhould ſeem meet."

The matter of the above petition having been fully heard by the Houſe of Commons, in the early part of the year 1755, that Houſe thought proper to addreſs his Majeſty, "that he would be graciouſly pleaſed to appoint proper and ſkilful perſons, to make a ſurvey of the works carrying on at Ramſgate Harbour, and give their opinions thereon; and what might be the moſt proper plan for finiſhing and completing the ſaid Harbour; to make

an eſtimate of the expenſe thereof; and that his Majeſty would be graciouſly pleaſed to cauſe ſuch plan or plans and eſtimate, together with an account of all the proceedings of the ſaid perſons, to be laid before the ſaid Houſe in the next ſeſſion of Parliament."

In conſequence, Sir Piercy Brett and Captain Deſmaretz were appointed to this ſervice; who, the latter end of the ſame year, delivered their plan, report, and eſtimate; and in the ſeſſion of 1756, a bill was brought into Parliament, which was much agitated, and canvaſſed; but it did not ultimately paſs into an act. Theſe proceedings however had the effect of putting a total ſtop to the works at Ramſgate.

SECTION III.

OCCURRENCES from the ſtoppage of the works in 1755, to their recommencement in 1761.

IT may in this place be proper to give a ſhort account of this ſcheme of the ſurveyors appointed, as nothing was in reality done upon it.

The report of Sir Piercy Brett and Captain Deſmaretz is addreſſed to the Lords of the Admiralty, and was printed in 1756. It almoſt ſets out with ſaying, that "according to the beſt of their judgement the works already made, and every plan hitherto impoſed, ſeem liable to very material objections;" they go on to ſay, "and we think it proper that the work done upon the contracted plan ſhould be taken up, and the materials made uſe of in carrying out the Weſt Pier."

It is however to be noted, that the whole of the work that had been done, excluſive of what concerned the contraction, was propoſed to make a part of their own ſcheme, being no other than the ſtraight walls or piers from the ſhore; but they propoſed, by engrafting upon them, to carry out the pier heads further by full 400 feet to ſeaward, than according to any of the plans that had been before exhibited, and which they ſuppoſed would place them in eight feet water. They alſo propoſed to make the opening of the Harbour's mouth right towards the Downs; whereas according to the advice of the eleven Captains, mentioned before, all former plans had exhibited that opening to be S. S. W. that is, about three points more weſterly than the ſituation recommended by thoſe gentlemen. The width of their opening, as ſhewn in their plan, is 275 feet; which is 75 feet greater width than any of the former ſchemes.

They further propofed, " for the better prefervation of fuch fhips and veffels which are fharp built, and liable to receive damage by laying a-ground, to have a bafon at the eaft fide of the Harbour, to be funk fixteen feet from the low water of a fpring tide, and partly inclofed with a ftone wall, as defcribed in the plan; where 50 or 60 fhips of 300 tons might always lie afloat in fmooth water: and they humbly conceived, that without fuch a bafon the Harbour would not anfwer the good purpofes intended by Parliament."

	£.	s.	d.
Eftimate for finifhing the Harbour, according to the plan - -	153,548	18	10
Add for completing the propofed bafon - - -	50,567	14	0
Total expenfe of the works propofed - -	£. 204,116	12	10

N. B. From the above the furveyors deduct for old materials to be drawn from the contracted walls, the fum of £.8,210 5*s*. 4*d*. fo that the total, at the foot of their eftimate, ftands £.195,906. 7*s*. 6*d*.

Such was the plan or fcheme of Sir Piercy Brett and Captain Defmaretz, upon which I fhall have a few ftrictures to offer when they come in courfe.

How it happened that this contracted plan of Mr. Ockenden's, which was productive of fo much mifchief and delay, came to be fo ftrenuoufly efpoufed by him, is not now eafy to fay; certain it is, that on a calm review it amounted to no more than to make a lefs Harbour at a greater expenfe than a larger; and that without any apparent inducement, unlefs what is alledged in the Committee's laft report, p. 89. is to be looked upon as fuch; viz. that the contraction will leave the Harbour large enough to contain more fhips than will ever have occafion to lie there at the fame time. How it happened that Mr. Etheridge fhould come into the fcheme is equally wonderful, as Mr. Etheridge appears to have been a very ingenious perfon, and which therefore can fcarcely be accounted for, but from jealoufy between him and Mr. Prefton, who it feems was againft the contraction. Finally; how it came to be adopted by the truftees at large, many of whom were able and experienced feamen, can only be accounted for by fuppofing Mr. Ockenden, having had occafion to confider works of civil engineery in his private affairs, became the leader of the majority; but ftill, why Mr. Ockenden, who was a man of fortune, and then was, or had been in Parliament, and does not appear to have had any immediate intereft in this bufinefs, fhould have wifhed in that ftrenuous manner to lead the truftees into a fcheme fo unneceffary, is to me at this day equally wonderful and unaccountable;

countable; but in this I am firmly perfuaded in my own mind, that had Mr. Etheridge fuffered Mr. Prefton to have had his due weight, this fcheme of contraction had never been brought forward; which would have faved the truftees much trouble, the truft much expenfe, and the work itfelf great lofs of time.

In this ftate the Harbour was at the time of this ftruggle, the eaft pier being carried out 757 feet from the fhore, and the weft 849. There however appears not the leaft apprehenfion from the public that the fituation of the Harbour at Ramfgate was improperly chofen; the effort was, that it fhould not be contracted, and its utility thereby diminifhed; nor did any feem to wifh it enlarged, Sir P. Brett and Captain Defmaretz excepted; and how muft thefe gentlemen have ftood aghaft, fuppofing their projected bafon (fixteen feet under low water mark) could have been at once executed, if they had afterwards found, on turning the curves of the piers, that the firft operation of nature was to fill it up, not only level with, but much above the level of the ground wherein it was dug.

After this total ftoppage of the works, a confiderable paufe followed; for we do not find the record of any tranfaction, till 30th April 1760, when the Board came to a refolution to proceed with the works, and gave an order for ftone and other materials neceffary for the purpofe. It may indeed feem extraordinary, that in the laft four years nothing was done. But I have been informed that the truftees were totally at a lofs what to do, as the works had been entirely fufpended, and no new act of Parliament made to chalk out what was to be done. In this interim, I underftand, the truftees applied to the Houfe of Commons, and alfo to the Lords, and were told verbally, that as nothing had been done to fufpend or alter their original powers, the beft way would be to proceed according to their beft difcretion. Accordingly the 20th June 1761, a Committee, by appointment of the Board, affembled at Ramfgate, and reported that it would in the firft place be neceffary to take up the contracting walls; of which they ordered a beginning.

SECTION IV.

TRANSACTIONS of the Truftees from the recommencement of the work in 1761, to the end of the year 1773; when the Committee preffed the Board to confider of more effectual means for cleanfing the Harbour.

A COMMITTEE, by appointment of the Board, met at Ramfgate the 25th June 1762, and reported that a good deal had been done in laying frefh foundations, and taking up the works

works of the contraction. Little had been then done at the eaſt head; and they recommended the works to be for the preſent carried on at the weſt head only *.

The ſeveral ſucceſſive committees of viſitation chiefly contented themſelves with reporting the progreſs of the work. That of Auguſt the 25th 1766, particularly mentions that the work of the fourth kant or flexure of the eaſt pier towards the weſt, was then going on, and the ſecond kant of the weſt pier was in hand. "That the Committee obſerved a collection of ſand in the harbour, increaſing under the eaſt head, near the ſtairs; and recommended, as the principal work for the next year, to finiſh the weſt head as ſoon as poſſible; which they hoped would prevent a further increaſe."

Till this viſitation, the works of Ramſgate Harbour (the ſtoppage from the contracted plan excepted) appear to have gone on with alacrity, and in full confidence of every degree of ſucceſs that had been expected; but it was now a mortifying ſight to the truſtees to find, that no ſooner had they begun to bend the walls towards one another, ſo as to afford protection as a harbour for ſhipping, than ſand began to collect, threatening to choak it up. This ſtruck the truſtees with ſo much chagrin, that the year 1767 had no viſitation; and in July 1768, after reporting the progreſs of the walling, they only recommended the work to be continued at the weſt head, without mentioning the ſtate of the ſand †.

The ſucceſſive accounts from Ramſgate contained ſo little of conſolation, or hopes of amendment, that the years 1769 and 1770 paſſed without a viſitation from the truſtees; but the next year the Committee's Report, which bears date Ramſgate, 25th Auguſt 1771, after ſtating the progreſs, and that the eaſt head was founded, acquaints us, that the Committee, in order to fix the entrance of the harbour, directed three poles with flags upon them, to be erected one at 200 feet, one at 250, and the third at 300 feet from the eaſt head, which laſt was then found to be twenty-five feet diſtance from the work of the weſt pier; and that the Committee, after taking ſeveral different views of the harbour, and upon mature conſideration, recommended that the entrance be 300 feet; and Mr. Preſton was then directed to prepare a proper finiſhing for the weſt head, agreeable to thoſe dimenſions.

* In this report mention is made of a contract for getting ſtone upon the ſea ſhore under the cliffs at Lyme Regis in Dorſetſhire, for burning into lime. For the qualities of this lime, ſee Smeaton's account of Edyſtone.

† The moſt ſtriking incident of this report was, that a veſſel with lime-ſtone from Lyme had run foul upon the works, and done them conſiderable damage, which ſhews this lime to have been in uſe at Ramſgate.

The

The Committee conclude their Report with obſerving, that though a hopper and two lighters had been employed ſince January 1770 to empty the harbour, yet they were ſorry to inform the truſtees, that the ſand had much increaſed therein; but that they had given directions to continue, with the utmoſt diligence, to do every thing in their power to make the harbour uſeful; and recommended to the Board to conſider if they could find out a more effectual method.

The Committee's Report of 1772, comprehends only the report of progreſs; the two heads being now in great forwardneſs.

Ramſgate, 31ſt Auguſt 1773, the Committee, after reporting progreſs towards finiſhing the heads, and that an engine had been fitted to a lighter for taking up ſand, and another Engine for throwing up ſand had been repaired, add that they could not help expreſſing their great concern in finding a vaſt quantity of ſand and ſullage lodged in the harbour, notwithſtanding that ſince January 1770 upwards of 52,000 tons had been taken out at an expenſe of £1,100, and it was feared it was rather increaſed than diminiſhed; and furthermore that the men employed herein refuſed to work without an increaſe of price.

The Committee deſired to remind the Board that in 1771, the gentlemen expreſſed their apprehenſions on the ſame account; and recommended it to the Board to conſider of ſome more effectual method of clearing the harbour; that in conſequence thereof the Secretary had directions to write to Mr. Smeaton, that the truſtees would be glad to have his advice upon the clearing and deepening of the harbour; but as the Committee were informed that he could not attend them that year, on account of a pre-engagement of his to go to Ireland, the Committee therefore adviſe nothing more to be done, till the opinion of that gentleman, or ſome other able engineer, could be had. The Committee however obſerve, that of the ſand thrown over the eaſt pier, conſiderable part returns with the tide, and ſettles in the harbour: therefore ſhould the Board think it adviſeable to continue taking up the ſand, &c. they recommend it to be taken 200 feet from the eaſt head, and 400 feet range along that ſide; and that it be carried up in the harbour within the 119 feet of croſs wall now building; and to prevent its waſhing out again to build another wall joining that, right in towards the cliff.

SECTION

SECTION V.

PROCEEDINGS of the Trustees from the beginning of the Year 1774 to the delivery of Mr. SMEATON's Report, and Transactions upon it, to the end of the Year 1778.

RAMSGATE, 6th April 1774, Mr. Smeaton attended a committee of nine trustees and the secretary.

The storekeeper and harbour-master were ordered to prepare an account of all the sand and sullage that had been carried out of the harbour, for the information of Mr. Smeaton. The harbour-master, foreman mason, and boatmen to attend him, in taking soundings, &c. In consequence of which he proceeded to make experiments upon the quantity and nature of the silt brought in, and to investigate every matter that appeared to him necessary to make a full report upon the subject of cleansing the harbour now before him.

The Committee further report that Mr. Preston laid before them a plan for cleansing the harbour, by harrowing up the sand, so that it might mix with the water, and be carried out with the ebb tide; and he was ordered to prepare a model of the machine for that purpose, as soon as possible, and send it for the inspection of the Board.

The 27th August the same year, the Committee again met at Ramsgate, and mention that a quantity of stone had been laid to secure the outer end of the east head; and that 260 tons of Portland had been taken out of the foundation of the contracted wall.

Mr. Preston now produced a model for cleansing the Harbour; in consequence, the Committee gave directions for making a number of rakes for stirring up the sand in the Harbour; and the 29th the Committee stationed fourteen men with the new rakes at the west side of the Harbour, at two-third ebb, and attended their working till flood; and ordered them to continue working every tide for seven or eight days; and that stakes properly marked should be driven where they worked, and a marked staff to be got by the harbour master, to take the depth of the sand at the centre, within and without the Harbour's mouth, to ascertain the effect of the rakes in reducing the sullage of the Harbour.

24th October, Mr. Smeaton transmitted his report on Ramsgate Harbour, in consequence of his survey of the 6th April before mentioned; an abstract and extracts of the most material parts thereof, are as follows:—

"Having

"Having been consulted by the trustees of the Harbour of Ramsgate, upon the best and most effectual method of clearing the harbour from silt gathered therein, having carefully viewed the said harbour in April last, in the presence of a Committee of trustees, and having taken such soundings, admeasurements, and other observations as appeared necessary; having also considered the several plans and papers since put into my hands, by the Board, it appears to me as follows:—

"That a large mass of silt, consisting partly of mud but chiefly of very fine sand, has been brought into the harbour by the tide, the tide water upon this part of the coast being charged with a considerable quantity of mud and sandy matter, whenever it is agitated by the wind, accompanied with a quick flowing tide. This silty matter being thus carried into the harbour along with the water that contains it, and there finding a place of repose, settles to the bottom; and as there is nothing to raise the mud upon the reflow, the water quietly ebbs out of the harbour, leaving the silt behind. And as the same causes constantly operate to produce the same effects, a continual increase of silt must be expected to take place, till some cause is brought to operate in a contrary way.

"This is the natural tendency of all harbours; for wherever there is mud or matter to deposit, an addition to the soil is the natural consequence of a place of repose; and a deposition and increase must take place, unless there are powers either natural or artificial to produce a contrary effect."—"The common natural power is a fresh water river, which continually tending towards the sea, and often, in time of floods, with great impetuosity, makes an effort to carry out whatever opposes it. The sand and silt therefore brought in by the tides, is carried out by the torrent of fresh water. Harbours therefore that have no land water or back-water cannot naturally keep open for a large course of years *. These being the effects of the powers of nature, we must by no means wonder that the harbour of Ramsgate, into which and through which not the least rivulet or runner of fresh water takes its course, has obeyed this general tendency. For, in proportion as the work of the piers has advanced, the space being inclosed, and the water rendered more quiet, and in that respect more fit for the purposes of a harbour, in much about the same proportion has the silting taken place, and must continue to increase till the area of the harbour becomes dry land, and instead of a receptacle for ships, exhibits a field of corn; that is, unless recourse be had to such artificial means as have the due efficacy.

"How far these effects were, or might have been, foreseen before the harbour was built; or being foreseen, how far it might have been proper to build a harbour there, is

* Large natural harbours or arms of the sea will necessarily be a long time in filling.

not

not now the question. The fact is, that a noble piece of masonry has been erected, at a very considerable expense, inclosing a large area in a place where a harbour must doubtless be of very great utility; in case the ground so inclosed remained as clear of silt as it was before its inclosure. The question therefore now is, what in effect you put to me; how to make it as useful as possible, and at the most moderate expense?"

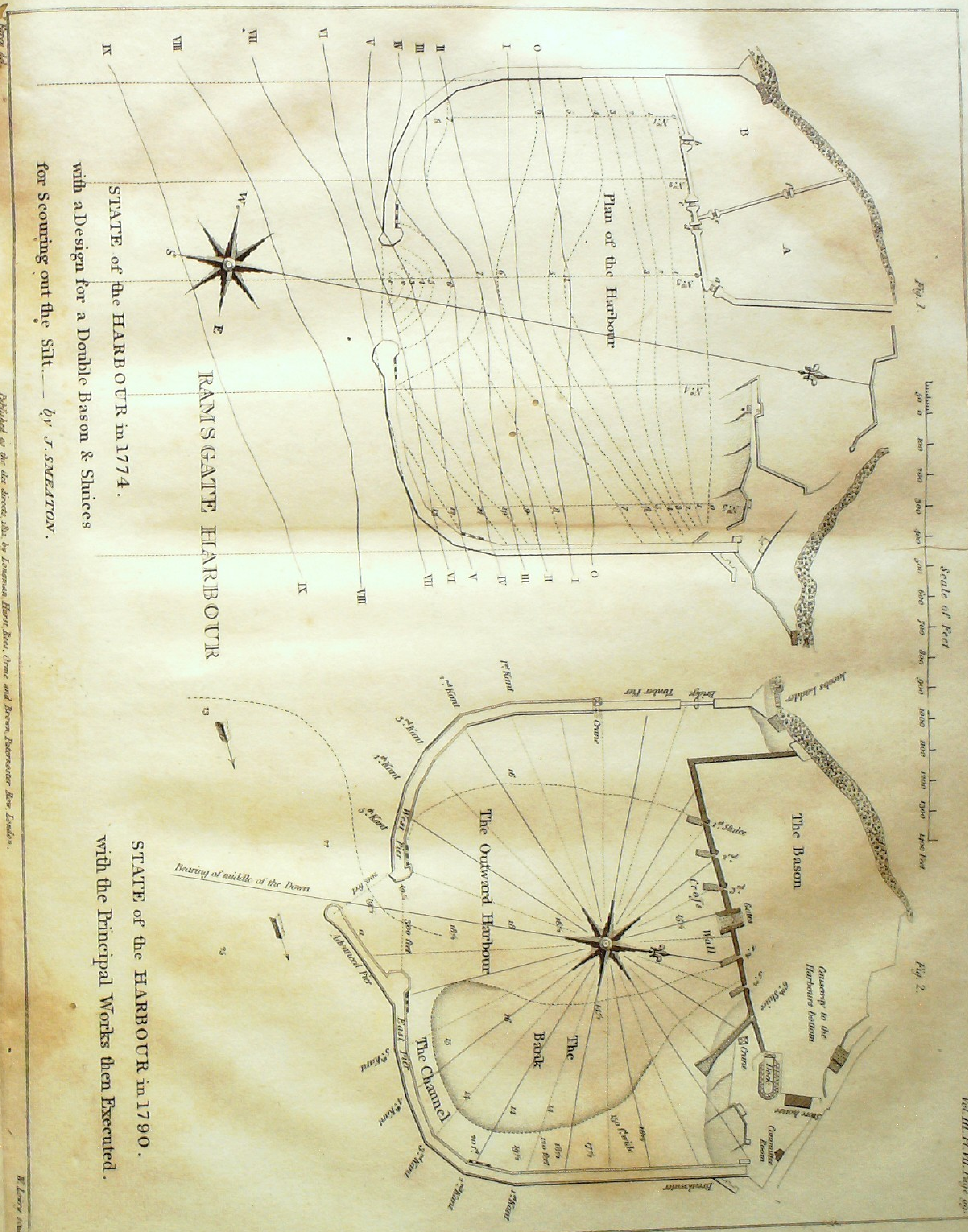
In the course of this report, it is stated from actual computation, that at this time there was not less than 268,700 cube yards of silt in the harbour: that the two barges then employed by the trustees, with ten men each, got about seventy ton of silt per day: and supposing them capable, from weather, regularly to work at this rate, which is scarcely possible, and that a ton of silt will be a cube yard; of which, in reality, it is much short; yet the harbour at this rate would be above twelve years in clearing, even supposing that no fresh silt were to come in during the time.

It is further shewn, that the whole harbour contains forty-six acres; and that the area of the external harbour where the silt chiefly lies, being thirty acres and a half, one tenth of an inch in thickness over this whole area, would amount to 410 cube yards, or tons; and this at seventy tons per day, would take a week to clear. Now supposing the mud to have come in at this rate only, the present mass, independently of what had been carried out, would have taken twelve years and a half to collect: but as it has been chiefly collected since the inclosure of the harbour, by the curves having been got above half tide *; the increase of silt could not be reckoned at less than double that quantity, or one fifth of an inch per week; which would afford a continual employ for four barges; and therefore that this, with the clearance of the present accumulation, and that their work must in reality fall short of the calculation, would render the whole so tedious a business, that it by no means appears to be the cheapest, or most effectual means of clearing the harbour; which was the question before Mr. Smeaton. He therefore proposed, " a method " of procuring an artificial backwater by means of sluices."

" Where no fresh water is to be procured, as is the case at Ramsgate harbour, the only resource is to construct a pool or bason to take in the sea water; the tide having there a considerable rise and fall. This has been done in many cases abroad, and particularly in the low countries, and in some cases in England; but the method has fallen into disrepute here, by its having been found, that the bason into which the tide water has

* It was only at the visitation of August 1766, that the growing of the sand was first noticed by the trustees.

been



been received, has itself in a moderate ſpace of time filted up and become uſeleſs.— A method however ſuggeſts itſelf to my mind, though I do not remember to have any where ſeen it put in practice, of keeping the baſon equally as clear as the harbour intended to be cleaned thereby; and that is by dividing the baſon into two parts, by a partition, with a ſluice, or ſluices, capable of retaining the water in either while the other is empty.; for by this means they can reciprocally be made a baſon for clearing each other; and be both united for clearing the harbour."

The harbour of Ramſgate is very well adapted for the execution of this ſcheme. It has every where a ſound bottom of chalk, upon a regular decline from the cliffs towards the harbour's mouth, and from thence out to ſea. The ſet of the tide, which is pretty briſk at particular times, runs croſſways upon the harbour's mouth, ſo that as ſoon as the ſand is waſhed to the outſide of the heads by the artificial current, the natural current of the tides will waſh it away, and effectually prevent any bar from being formed before it.

"The ſand itſelf is of ſuch a nature as to give the leaſt reſiſtance poſſible to a ſmart current; for the grains being ſmall, though hard, and ſpecifically heavy, yet not being united by any loamy or tenacious matter, will give way to the impreſſion of a current."

This report was accompanied with a plan, (ſee Plate 7. Fig. 1.) diſtinctly ſhewing the mode of executing the ſcheme; which was by carrying forward the croſs wall, already begun for another purpoſe, in an eaſtern direction to a certain point.

A ſpace thus marked out was ſhewn to contain eight acres of water; which was propoſed to be divided into two baſons of four acres each; which it was ſhewn would produce a very powerful effect in cleanſing the harbour, inſomuch as in ſix months to be likely to make from fifteen to ſixteen feet water, at a common neap; and from eighteen to nineteen feet at common ſpring tides.

Thoſe baſons were deſigned to have nine draw-gates, four upon the weſternmoſt, and five upon the eaſternmoſt baſon; the whole being pointed in three different directions; two towards the curve of the weſtern pier; four towards the harbour's mouth, and three towards the curve of the eaſtern pier.

To give the ſluices all the effect poſſible, it was propoſed to conſtruct a caiſſon, ſhaped ſomething like the pier of a bridge; which being floated to its place, and there ſunk, after being

being put in a proper direction, might be uſed to divert the current to the right hand or left, as might be wanted. This report concludes with obſerving, that after the ſilt is carried by the ſluices without the harbour's mouth, there is not any danger of its lodging there; becauſe, having particularly examined the outſide, and found all clean of ſand, there is no doubt but that the ſame cauſe that now operates to keep that ground clean, will continue to do ſo. Furthermore, that the ſame means that will clear the harbour, will keep it clear: and that it might be expected that the playing of the ſluices eight tides at each ſpring tide will preſerve it.

This report, tranſmitted to the Board in October 1774, lay before them till Auguſt 1775, when the committee at Ramſgate took into conſideration Mr. Smeaton's plan, for making the upper part of the harbour into a baſon or baſons, for ſcouring the harbour by means of ſluices. The committee likewiſe conferred with Mr. Preſton, and conſidered a plan of his for cleanſing the harbour, by making all the upper part into a baſon, for ſcouring it with ſluices; and Mr. Preſton now declared his opinion that it would clear away the ſilt to low water mark, wherever the power of the ſluices could reach *.

After further conſideration of the matter before the Committee, they being cautious in adopting a ſcheme of expenſe, gave directions in order to try an experiment what effect an artificial back water might have, for a lighter of fifty tons to be ſcuttled, ſeventeen inches deep, and fourteen inches broad on the ſtarboard bow; this to be placed near the end of the croſs wall, and filled with water. The ſluice being opened at low water, it ran out in a few minutes, and made a cavity in the ſand of ſeveral feet in diameter and depth. But the ground here being higher before the head of the lighter than at its ſtern, the water ſpread a ſtern, without making the impreſſion expected.

The Committee now ordered the lighter to be removed, and placed between the croſs wall and the harbour's mouth; and there repeated the experiment. The firſt tide the water being let out, made a greater impreſſion than before; but yet ſpread itſelf without making any channel.

A channel was then ordered to be made and guarded with planks, and in the afternoon (the lighter remaining in the ſame place) the experiment was tried again; and the cavity

* Mr. Preſton ſeems here to have loſt ſight of his ſcheme for harrowing up the ſilt, propoſed to the Board in April 1774; and which was tried by the Committee in Auguſt following: in ſhort, ten months after the delivery of Mr. Smeaton's report, Mr. Preſton ſeems to have come to a different view of this buſineſs to what he had before.

made

made by the diſcharge of the ſluice, was about ſeven feet wide at the ſurface of the ſand, and ſix feet deep to the bed of the chalk; and a channel was then forced of near 100 feet long. The Committee now ſeeing the effect of the confinement of the water, and of repeated diſcharges, tried the experiment of the barge twice more, when the hole was rendered ten feet wide upon the ſurface of the ſand, ſix feet deep to the chalk, and three feet wide upon the bed of chalk; the channel being full 100 feet long; and the ſtream carried ſome clouds of ſand to a conſiderable diſtance. Theſe experiments were tried in the preſence of Meſſrs. Barker, Slater, Aubert, Laprimaudaye, Bennet and Bennet junior, who all became fully ſatisfied of the effect to be expected from ſluices when made in large.

Mr. Barker and the two laſt mentioned gentlemen continuing at Ramſgate another week, in that time further conſulted with Mr. Preſton, upon the eligibility of carrying the wall already begun, acroſs the harbour to the old pier; in order to make *all* the upper part of the harbour into a baſon for ſcouring it with ſluices: and after conferring with ſeveral old men of the town, reſpecting the moſt practicable method of clearing the harbour, Mr. Preſton was ordered to prepare eſtimates of the ſtone and timber for the croſs wall and ſluices, and Mr. Stead the carpenter, to prepare an eſtimate of the expenſe of making one ſluice, and the time neceſſary to conſtruct it; and to make a model of one, to be ſent up to town for the inſpection of the Board. The reſult was, that the Committee finally recommended to the Board, that Mr. Preſton's plan for cleanſing the harbour by means of ſluices ſhould be carried into execution with all poſſible diſpatch.

In the year 1777, Mr. Preſton the maſon being then dead, Mr. Hurſt, who had been foreman under him from the beginning of the work, appears as maſter maſon, and Mr. Henry Cull as his foreman. A conſiderable progreſs with the croſs wall and ſluices, as well as other works of the piers, was reported on this viſitation as the produce of this year's work; as alſo, by the Committee of July 1778, a ſtill further progreſs in the works of the croſs wall; the floor of the fifth ſluice being laid; and the great gates, and five ſluices framed. The Committee now perceived a greater agitation of the ſea within the harbour, than before the croſs wall was built ſo far forward; and recommended a range of piles and planking to be erected on the eaſt ſide of the harbour to abate that agitation; and be a means of making that part of the harbour, which is the deſirable ſtation for the ſhipping, more ſafe and quiet. This to be done with all poſſible diſpatch, and the croſs wall to be carried out with all expedition.

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SECTION VI.

The firſt Starting and Effects of the Sluices in 1779, with the Account of their Operation, to the end of the Year 1781.

1779.—THE Committee of the 9th Auguſt report the range of piles driven, and in part planked, the works of the croſs wall much advanced; Mr. Barker, earneſtly deſiring to ſee a trial of theſe works, though far from finiſhed, or the walls got up to high water, yet, the 1ſt, 2d, 3d, and 4th ſluices being fixed, made a ſtrenuous effort to get the great gates hung, and the fifth ſluice made capable of penning in the water while he ſtaid at Ramſgate. Meſſrs. Aubert and Laprimaudaye at this time arrived, and Mr. Paris attending: the gates being hung, and all the ſluices put down at high water, the Committee attended at low water, and having ordered all the men to be ready, and placing them in proper proportions at the gates and ſluices; the men applied themſelves to the handles to ſtart the ſluices, when the ſpindles upon which the wheels were fixed, broke upon the firſt attempt of every ſluice; ſo that at preſent there was no poſſibility of raiſing any more than the two ſluices in the gates, and which indeed were drawn by tackle blocks; but the force and power of the ſtream iſſuing through theſe two ſluices only, was ſo amazingly great, that in its immediate action it forced up the Chalk Rock to the depth of ſix and ſeven feet, and carried pieces of it of three to four hundred weight, to the diſtance of 60 or 70 feet; and in its courſe, cleared away the ſilt and ſullage down to the chalk, to low water mark; the ſtream continuing ſtrong 2 or 300 feet, without the Harbour's mouth. Some defects were found in the wall and other parts, which being remedied as well as time would permit, the water was ordered to be pent up in the baſon again; and the tackle blocks to be applied to the ſluices, as well as to thoſe of the gates; yet though all the people were properly placed, there was no poſſibility of raiſing more than two ſluices, excluſive of thoſe of the gates, notwithſtanding 30 or 40 men heaved at each ſluice. However, with a great deal of labour and difficulty, the Committee afterwards got thoſe ſluices ſtarted twice again, and were happy to inform the Board, that the effects produced exceeded the general expectation: the ſtream of water carrying the ſand a great way beyond the entrance of the Harbour, in ſuch quantities, that the ſea at the diſtance of a mile and a half, was obſerved to be exceedingly thick and foul. The deep channels through the ſand in the harbour, appeared ſimilar to the beds of rivers; and the general voice ſeemed unanimous in teſtifying their firm belief, that the back water would effectually cleanſe the harbour.

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To deviſe ſome proper method to ſtart the ſluices, ſeemed a difficulty not eaſy to be got over, as the people could not contrive any purchaſe adequate to the purpoſe. But Mr. Aubert obſerving that the planking of the ſluices were put to draw croſs ways of the plank, which operating in a rough groove of ſtone muſt neceſſarily cauſe a great friction; orders were immediately given for the trial of one made in a different way, and they then found it to work with ſufficient eaſe; and the ſpindles being repaired and made of wrought iron, the water was again pent up, and it was diſcharged in the preſence of the before mentioned gentlemen, and of Mr. Sibley and Mr. Lutkens, who were then arrived, and things were now found much better adapted to do their duty; but the Committee finding that the rapidity of the ſtreams of water iſſuing from the ſluices had, by its great power, forced up the chalk rock to a conſiderable depth; inſomuch that the croſs wall would be in great danger of being undermined; they gave orders to the maſon and carpenter to conſtruct proper aprons for preventing thoſe effects in future.

The Committee further report, that during the laſt winter it had been a prevailing complaint that the Harbour had been greatly agitated, and at ſome particular times rather unſafe for ſhips to lie in; which was not the caſe before building the croſs wall, as the ſea then broke and ſpent itſelf upon the ſhore: and as it had been obſerved that the ſea moſtly ranges along the weſtern pier, and that the croſs wall ſtopping and repelling the ſwell, it returns on account of its not having any vent or outlet, and cauſes that great diſturbance and agitation now complained of. Under theſe circumſtances, the Committee recommended that about 2 or 300 feet of the weſtern end of the croſs wall (or what might be neceſſary) ſhould be taken down; and that from thence a wall ſhould be built up towards the cliff; and furthermore, that about 80 or 100 feet of the timber pier ſhould be taken away, beginning about the end of the croſs wall, and the opening to extend towards Jacob's Ladder; the Committee having great hopes that this plan would render the Harbour more ſafe and quiet.

The Committee further mention it as a general opinion, that another ſluice would be found neceſſary to ſcour the upper or northern angle of the eaſt pier; and therefore recommended that a ſluice ſhould be made from the angle in the old pier, to be carried through the work yard to the end of the carpenter's ſhop.

It may here be proper, before we go on further, to advert to the ſtate in which the Harbour really was previouſly to the trial of the ſluices: indeed, it was ſo bad that I do not find any memoranda have been preſerved of its condition. I muſt therefore recur to the ſtate in which I found it at the time of my ſurvey in 1774. At that time, in the very centre of the outward Harbour the ſand was accumulated to an elevation four feet above the

the level at which the thresholds of the present gates are laid; and this being then the best, that is the deepest part of the Harbour, vessels drawing above ten feet water could hardly be said to get into it even at spring tides. At low water there was no water to be seen in the Harbour, except a small roundish area reaching a little within the pier heads at neap tides, and at spring tides none but what was immediately between the heads. Under the curve of the east pier, which was the proper birth for large vessels (could they have occupied it), the sand lay considerably higher; so that in the third angle, which is naturally the best birth, there was no less than thirteen feet in depth of silt, lying upon the chalk bottom, which would be seven feet above the level of the present threshold of the gates; and if this was the condition of the Harbour in 1774, we must conjecture how much worse it had become in this year 1779, when the sluices were first brought into action, as has been described, notwithstanding that the barges had been all the time employed in getting the sand out as fast as they could. In this forlorn state the Harbour of Ramsgate had become justly reprobated by the public, as a work not having the least appearance of utility, or likelihood of being made useful.

1780.—The Committee's report dated 7th August, notices that 150 feet of the cross wall had been taken down, and a considerable progress made with the returning wall towards the cliff; and that 100 feet of the timber pier had been removed to make an opening; which was then made and passable by a wooden bridge, with a stone pier in the middle. Aprons being also laid to all the sluices, and examined by Mr. Barker, the water was ordered to be shut in, and Messrs. Slater and James arriving, took their station at the pier head, and found that the stream ran exceedingly strong beyond the mouth of the Harbour, carrying the sand into the tide.

The fifth sluice having not yet been put in action, it was ordered to be forthwith completed; and Mr. Barker finding a great bank of sand extending eastward of the fourth sluice, directed the harbour-master to place two barges to turn the current of the water to run upon the point of the bank. The fifth sluice being completed during Mr. Barker's stay, he ordered it to be run without the rest, and found the effects of it to be amazingly powerful; insomuch that in a few times running it entirely cleared away the sullage within a few feet of the old pier, and carried out of the Harbour's mouth great quantities of sand. Mr. Barker being desirous to have all the sluices completed as soon as possible, and as there was the greatest reason to believe that the fifth, with an addition of a sixth sluice, would operate very powerfully in cleansing the east side of the Harbour, which, as already noticed, is the principal birth for shipping, he ordered the digging for the foundation of the conduit of the sixth sluice to be begun; and before he left Ramsgate, saw a considerable

able length of the foundation dug, and the stone work itself begun. He also left directions to run the sluices once in 24 hours, and ordered the chalk that had been forced up by the running of the sluices, to be laid under the cross-wall to secure its foundation.

Observing now, that a prodigious quantity of silt accumulated in the bason or upper harbour, and that the clearing it would make it vastly more commodious for * shipping; by way of experiment he ordered the sluices to be put down at low water, and that one sluice only should be opened about an hour before high water; for it was supposed that the action of the water issuing into the empty bason, would stir up and loosen the silt so as to facilitate its getting out when the sluices acted in the contrary direction. The experiment was twice tried and found to have some effect; but the power of the water seeming to endanger the foundation of the wall, he found it more adviseable to order that six or eight men should attend at the running of the sluices, to shovel down the silt into the current, when the water was sufficiently down to admit thereof.

1781, Committee's report, *August 6th*.—The work at the fifth and sixth sluice being now completed, a new channel was ordered to be dug through the sand from the sixth sluice, and a couple of barges to be laid, so as to direct the water thereof through the channel. In a few times running, it was found that the bank was considerably decreased, and that the water of this sluice flowed so high as to overtop the conduit wall; from the whole of the operation of the sluices there appeared the greatest reason to believe that the fifth and sixth sluices, and particularly the last, would be effectual in cleansing the east side of the harbour.

From this era Ramsgate Harbour began to put off that forlorn appearance of a repository of mud, and to assume one more respectable than it had done for 15 years before; and the trustees seeing that they were now become competent to the cleansing of the outward harbour, and finding the great utility of the bason, turned their mind towards the clearing of that from the sullage gathered therein; for which various propositions presented themselves; viz. First, the barges to be filled at a price per ton, as had been done in the outward harbour: Secondly, the sullage to be taken up and lead out with carts: Thirdly, a premium of three-pence per load to be offered to the farmers to take it out as manure: Fourthly, the barges to be filled by the labourers, and carried out by day works: Fifthly, the barges to be filled with water, and being scuttled, to play upon the bank of sullage at low water, in the manner the experiment was conducted; labourers being employed to throw down the bank of sand. The two last of which seemed then the most practicable schemes.

* Necessary also for the purpose of a backwater.

 SECTION

the level at which the threſholds of the preſent gates are laid; and this being then the beſt, that is the deepeſt part of the Harbour, veſſels drawing above ten feet water could hardly be ſaid to get into it even at ſpring tides. At low water there was no water to be ſeen in the Harbour, except a ſmall roundiſh area reaching a little within the pier heads at neap tides, and at ſpring tides none but what was immediately between the heads. Under the curve of the eaſt pier, which was the proper birth for large veſſels (could they have occupied it), the ſand lay conſiderably higher; ſo that in the third angle, which is naturally the beſt birth, there was no leſs than thirteen feet in depth of ſilt, lying upon the chalk bottom, which would be ſeven feet above the level of the preſent threſhold of the gates; and if this was the condition of the Harbour in 1774, we muſt conjecture how much worſe it had become in this year 1779, when the ſluices were firſt brought into action, as has been deſcribed, notwithſtanding that the barges had been all the time employed in getting the ſand out as faſt as they could. In this forlorn ſtate the Harbour of Ramſgate had become juſtly reprobated by the public, as a work not having the leaſt appearance of utility, or likelihood of being made uſeful.

1780.—The Committee's report dated 7th Auguſt, notices that 150 feet of the croſs wall had been taken down, and a conſiderable progreſs made with the returning wall towards the cliff; and that 100 feet of the timber pier had been removed to make an opening; which was then made and paſſable by a wooden bridge, with a ſtone pier in the middle. Aprons being alſo laid to all the ſluices, and examined by Mr. Barker, the water was ordered to be ſhut in, and Meſſrs. Slater and James arriving, took their ſtation at the pier head, and found that the ſtream ran exceedingly ſtrong beyond the mouth of the Harbour, carrying the ſand into the tide.

The fifth ſluice having not yet been put in action, it was ordered to be forthwith completed; and Mr. Barker finding a great bank of ſand extending eaſtward of the fourth ſluice, directed the harbour-maſter to place two barges to turn the current of the water to run upon the point of the bank. The fifth ſluice being completed during Mr. Barker's ſtay, he ordered it to be run without the reſt, and found the effects of it to be amazingly powerful; inſomuch that in a few times running it entirely cleared away the ſullage within a few feet of the old pier, and carried out of the Harbour's mouth great quantities of ſand. Mr. Barker being deſirous to have all the ſluices completed as ſoon as poſſible, and as there was the greateſt reaſon to believe that the fifth, with an addition of a ſixth ſluice, would operate very powerfully in cleanſing the eaſt ſide of the Harbour, which, as already noticed, is the principal birth for ſhipping, he ordered the digging for the foundation of the conduit of the ſixth ſluice to be begun; and before he left Ramſgate, ſaw a conſiderable length of the foundation dug, and the ſtone work itſelf begun. He alſo left directions to run the ſluices once in 24 hours, and ordered the chalk that had been forced up by the running of the ſluices, to be laid under the croſs-wall to ſecure its foundation.

Obſerving now, that a prodigious quantity of ſilt accumulated in the baſon or upper harbour, and that the clearing it would make it vaſtly more commodious for * ſhipping; by way of experiment he ordered the ſluices to be put down at low water, and that one ſluice only ſhould be opened about an hour before high water; for it was ſuppoſed that the action of the water iſſuing into the empty baſon, would ſtir up and looſen the ſilt ſo as to facilitate its getting out when the ſluices acted in the contrary direction. The experiment was twice tried and found to have ſome effect; but the power of the water ſeeming to endanger the foundation of the wall, he found it more adviſeable to order that ſix or eight men ſhould attend at the running of the ſluices, to ſhovel down the ſilt into the current, when the water was ſufficiently down to admit thereof.

1781, Committee's report, *Auguſt 6th.—The work at the fifth and ſixth ſluice being now* completed, a new channel was ordered to be dug through the ſand from the ſixth ſluice, and a couple of barges to be laid, ſo as to direct the water thereof through the channel. In a few times running, it was found that the bank was conſiderably decreaſed, and that the water of this ſluice flowed ſo high as to overtop the conduit wall; from the whole of the operation of the ſluices there appeared the greateſt reaſon to believe that the fifth and ſixth ſluices, and particularly the laſt, would be effectual in cleanſing the eaſt ſide of the harbour.

From this era Ramſgate Harbour began to put off that forlorn appearance of a repoſitory of mud, and to aſſume one more reſpectable than it had done for 15 years before; and the truſtees ſeeing that they were now become competent to the cleanſing of the outward harbour, and finding the great utility of the baſon, turned their mind towards the clearing of that from the ſullage gathered therein; for which various propoſitions preſented themſelves; viz. Firſt, the barges to be filled at a price per ton, as had been done in the outward harbour: Secondly, the ſullage to be taken up and lead out with carts: Thirdly, a premium of three-pence per load to be offered to the farmers to take it out as manure: Fourthly, the barges to be filled by the labourers, and carried out by day works: Fifthly, the barges to be filled with water, and being ſcuttled, to play upon the bank of ſullage at low water, in the manner the experiment was conducted; labourers being employed to throw down the bank of ſand. The two laſt of which ſeemed then the moſt practicable ſchemes.

* Neceſſary alſo for the purpoſe of a backwater.

SECTION VII.

TRANSACTIONS from the Proposal of a Dock in 1782, to and inclusive of SMEATON's third visit to Ramsgate in the Summer of 1787; with the Transactions to the Death of John Barker Esquire, in the Autumn of that Year.

1782, COMMITTEE's report, dated Ramsgate, 5th August.—On this visit Mr. Barker had the highest satisfaction in finding the great improvement that had been made in the harbour by means of the sluices, and particularly in the middle part; and that in the channel under the east pier, there was full nineteen feet water at a spring tide. This improvement was greatly owing to a temporary fence having been made, for turning the water of the fifth sluice to operate along with that of the fourth; but which having been carried in an irregular line, so that the water went over it, did not produce all the effect it might have done; and therefore, by way of expedient, he ordered the barges and lighters to be laid along-side the fence, the more effectually to confine the waters and grind a channel. He had also high satisfaction in finding, that by the means proposed last year, a great part of the bason was now cleared of sullage down to the chalk; and that from the gates to the crane there were fourteen feet water at spring tides, and he supposed that at least 80 sail of vessels might be sheltered therein.

He found in the bason a Venetian vessel of 300 tons, that had been hove down, and her keel repaired; and also a Swedish ship of 340 tons measure, that had been unloaded of 1,700 quarters of wheat in the bason, and there undergone a thorough repair; and with pleasure observed that vessels brought in from the Goodwin Sands, made directly for the gates, and sailed into the bason without difficulty. Therefore, taking all these things seriously into consideration, and finding that this harbour was not only a place of shelter for ships in distress, but also for the repair of their damages at sea; two more articles seemed essentially necessary to make the harbour of that complete utility to the public, that now appeared near in prospect; and these were, a storehouse contiguous to the bason, for the reception of the goods that were thus obliged occasionally to be put on shore while the vessels were repaired; and a dock for occasionally taking in a vessel to be thus repaired. These seemed, indeed, matters so important and of such immediate concern, that Mr. Barker desired to have Mr. Aubert's advice, and that he would also bring down with him Mr. Smeaton, to advise with respect to the practicability of the dock, &c.

Messrs. Aubert and Smeaton immediately attended this summons; and all agreed that the storehouse would be of great utility as well as the dock; but that as the latter was

was likely to be a work of expense, it would be proper not to lay more burthen upon the trust, in the whole, than necessary; and therefore that it would be eligible to let an area of ground for a storehouse on lease to private adventurers, under certain restrictions; but that with respect to the dock, it would probably require that care and caution in construction, as not to make it eligible to be trusted to private execution.

In consequence therefore of my orders, I proceeded to inspect the ground, with a view to the building a dry dock for the graving and repairing of vessels; and to inform myself of every circumstance relative thereto, that could in its nature be then known.

On this visit, it was not with a small degree of satisfaction that I was eye-witness to the very great difference that there was in the condition of this harbour, to what it was in the year 1774, when I was last there: and that the hints suggested in my report of that year being carried into execution, had been attended with every prospect of success that could reasonably be expected.

The gates having been shut in, and having seen the operation of the sluices, what seemed to be now most wanting, was an increase of power so as to widen the channel under the east pier. And as I observed that the bringing of the stream of the fifth sluice to act along with the sixth, was but very imperfectly executed, to prevent loss of time I then staked out a curve for the direction of a fence or turnwater; which being temporarily executed with stakes and boards, and found to answer the end, has, with repairs, remained there to this day.

It was then complained, that the gates were much too narrow; but finding them thirty feet clear width, and therefore wide enough for the largest vessels then expected into the bason; I observed, that vessels any thing near that width could never venture to run in under sail. Nor did it appear to me, that those gates had ever been designed with that idea: for I found the entering angles were very little rounded, and the entering walls themselves upon a parallel; so that the least swerving of the vessels, to the right hand or left, would make them strike the stone work, unless in the case of small vessels where there was a good deal of width to spare. To remedy this inconvenience, I recommended to build flue walls, to project forward thirty feet, and in that length to splay out, or widen, five feet each, so that at this new entry the width would be virtually forty feet; and which might be deemed wide enough for securing the entry of vessels of thirty feet. I also noticed, that if the sharp angles of the stone work of the sluices were also properly rounded off, they would give a more full bore of water.

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The gates themſelves, alſo, being of too ſlight a conſtruction, were already got into ſuch bad condition, that I was deſired likewiſe to make a proper deſign for a new pair of gates *.

I afterwards took an opportunity of viewing the docks at Liverpool, and early in the year 1783 delivered, not only my deſigns for new gates for the baſon, with the ſlue walls, which were immediately ordered into execution; but for a graving dock with a timber bottom, like thoſe I ſaw at Liverpool, and which indeed appeared to me abſolutely neceſſary in a ſituation like Ramſgate. I knew that the natural bottom would be the ſame as that of the whole harbour, which was univerſally a chalk; and which, though it had never been proved by any excavation under low water mark that had been attempted to be kept clear of water, yet it might be reaſonably preſumed, that though the foundation was likely to be free from groſs ſprings, yet it would be ſubject to ſuch tranſpirations as could not take place in clay or ſolid ſtone, and would therefore need a wooden floor; and as in works of this kind it is uſual to call upon the deſigner, in caſe any thing in the nature of the ground or foundation turned out different from what was originally to be ſuppoſed, there could therefore be no neceſſity to give directions for every poſſible caſe and contingence.

1783, Ramſgate, 4th Auguſt.—Mr. Barker found that the ſtorehouſe recommended had been built; and that the ſharp corners of the ſluice walls had been rounded off, in order to give more water way; that a new fence of piles and planks had been executed, to unite the waters of the fifth and ſixth ſluices; that a hill of chalk in the baſon had been ploughed up and removed; that the eaſt ſlue wall of the gates had been carried up to the height and dimenſions ſpecified by Mr. Smeaton's plan; and that the weſt ſlue wall was in great forwardneſs, and he found it to be the general opinion, that theſe walls would greatly facilitate the entrance of ſhips into the baſon; and that the graving dock, already reſolved on by the Board, would be very ſerviceable in the repair of ſhips damaged at ſea, and brought in for that purpoſe. During Mr. Barker's long ſtay here at this viſitation, the new gates were actually hung, the water ſhut in, and every thing found to anſwer; ſo that, after ſeeing the ſluices run ſeveral times, he concluded that they would in every reſpect fulfil the intended purpoſe. He expreſſed himſelf as particularly happy in acquainting the Board, that the vaſt accumulated body of ſilt which formerly choaked up the baſon, was now entirely cleared away, and that ſhips from 200 to 400 tons might

* It was afterwards intimated to me, that, as the dry docks of Liverpool were eſteemed of the moſt complete kind for merchants ſervice, the truſtees would wiſh me to take an opportunity of ſeeing them.

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lie in the baſon with the greateſt eaſe and ſafety, and that in a conſiderable number: and ſays, " that in the courſe of laſt winter and ſpring, property to a very large amount had been preſerved, as ſeveral large ſhips with valuable cargoes were brought in and taken care of. The cargo of one large ſhip only being eſtimated at £35,000.; and that under Providence, it has been the means of preſerving many uſeful lives to their families, and to the community.

1784, Ramſgate, [illegible] July.—From Mr. Barker's report upon this viſitation it appears, that a new dock being determined upon by the truſtees to be built according to Mr. Smeaton's plan, it was immediately begun; and Mr. Barker laid the firſt ſtone 31ſt July, and the workmen were directed to proceed with all poſſible expedition *.

On this viſitation, Mr. Hurſt the maſon having been found incompetent to this work, was ſuſpended: this was attributed to a fit he had had two years before; but being an old ſervant, from the firſt commencement of the work, under Mr. Preſton, and always conſidered as a man acquitting himſelf well, Mr. Barker recommended it to the truſtees to allow him ſomething by way of ſubſiſtence. Mr. Cull therefore, his foreman, was recommended inſtead of Mr. Hurſt, as maſter maſon, and Mr. Speers to be his foreman.

Mr. Cull being conſulted by Mr. Barker, recommended that the thickneſs of the north wall of the dock ſhould be increaſed by two feet; and to build both the walls two feet higher than they had been ſet out in Mr. Smeaton's plan, to which there could be no objection. With reſpect to the floor, they apprehended no difficulty in making it of ſtone like that of the gates; thinking it more eligible than of wood, as being more durable, and not ſubject to the worm.

Mr. Barker had the great ſatisfaction to find that both the outward harbour and baſon had been greatly improved; as the channel under the eaſt pier had been conſiderably widened and deepened: and the ſullage of the baſon, being now entirely and conſtantly kept down, betwixt four and five feet depth had been gained at the upper end thereof.

During this viſit at Ramſgate, in a hard gale of wind which happened at N. E. Mr. Barker had an opportunity to be eye-witneſs to the more quiet and preferable ſtate that

* Here it may be proper to obſerve, that had Mr. Smeaton's plan been in reality complied with, it would probably have taken the whole of this ſeaſon to have completed, and laid down the timber floor; before a ſingle ſtone could have been laid: but it was thought proper to begin the walls according to Mr. Smeaton's lines, excluſive of the floor.

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the harbour was now in, to what it was before the weſternmoſt part of the croſs wall was taken down, and the opening made through the weſt pier, as has been deſcribed. The new ſtorehouſe now built by direction of the truſtees, he found to be a ſtrong and commodious building, convenient, and every way adapted for the reception of goods; as ſhips of 400 tons could range up cloſe under it, and unload their cargoes with the greateſt facility.

1785, Ramſgate, 5th Auguſt.—On this viſit Mr. Barker reports that the dock was in great forwardneſs; for the walls were built up twelve feet high, and that 3065 feet of pavement had been laid at the bottom. That the gates were made, and ready for hanging; and that the whole ſeemed to be an exceedingly good piece of workmanſhip; and that it was likely to be ready for uſe by February next. He notices that the worm prevailed much here, and ate the wood work of the ſluices to ſuch a degree, that he recommends every part to be of ſtone that can be.

He had the pleaſure to find every thing in an improving ſtate; and that the encomiums which he thought it only juſtice to beſtow upon the harbour the laſt year, had been more amply confirmed by the appearances in this. He ſays the whole body of ſullage in the outward harbour was certainly conſiderably diminiſhed; and the channel under the eaſt pier improved and widened, but ſtill not to that extent to ſatiſfy his wiſhes; or that was expected from the united waters of the fifth and ſixth ſluices; however, as the widening of this channel was of important conſideration, he ordered two of the barges to be laid cloſe in the channel; and ten or twelve men to fill them, as had formerly been done before the ſluices were brought to act. It was however obſerved to him by the ableſt pilots and ſeamen beſt acquainted with the harbour, that it would not in reality be well to have the whole bank of ſand taken away from the eaſtern ſide of the harbour; and they put a caſe, that ſuppoſing the harbour quite freed of this bank, and a ſhip coming in in a hard gale of wind, without anchors and cables; if there was nothing to bring her up, ſhe would be liable to be driven againſt the walling of the piers, and be knocked to pieces; they therefore ſtrongly urged the neceſſity of having a bank on the eaſt ſide of the harbour upon which ſhips might bring up.

He notices that it had been (and not long ſince) the reproach of this harbour, that it never could be made capable of receiving any thing but ſmall veſſels; but that now it was capable of ſheltering almoſt any merchant ſhips (Eaſt Indiamen excepted); and as a proof of it, a ſhip which was ſaid to be of 800 tons, took refuge in the channel of the eaſt pier laſt winter, and lay in the ſaid channel for two months; and a large Norway ſhip, called

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the Ebenezer, with upwards of 30,000 deals on board, got upon the Goodwin ſands, where her maſts and rigging were deſtroyed; yet ſhe was nevertheleſs got off by the Ramſgate boatmen, and brought into the channel of the outward harbour; though ſo water-logged that ſhe actually drew eighteen feet and a half water; and in a gale of wind that happened lately, about 30 ſail of veſſels, Engliſh and foreign, with valuable cargoes, the greater part of which having loſt their anchors and cables in the Downs, had been preſerved by being brought into the harbour and baſon, where they had every neceſſary aſſiſtance; ſome of which were then unloading their cargoes into the ſtore-houſe, being leaky and much damaged. Indeed it was, he ſays, now generally admitted, that within a very few years, the harbour had been improved, to a degree, even beyond what its warmeſt friends and promoters ever expected.

1786, Ramſgate, 5th Auguſt.—"Mr. Barker thinks it proper to acquaint the Board, that the dock is built, and is an exceeding neat piece of architecture; but the water unfortunately riſes up through the pavement, a great part of it having been heaved up and looſened. A diſagreeable circumſtance, equally unforeſeen as unexpected.—It is now perceived that there are natural ſprings which riſe in the bed of the dock; that theſe, with the great weight of water in the baſon, when it is ſhut in, united, have been ſo ſtrong in their effect as not only to break through the cement, but have in many places broken the paving ſtones; a circumſtance very mortifying, after ſo much pains have been beſtowed upon it." Mr. Barker, in conſulting with the maſter maſon upon the moſt probable means of preventing the waters riſing, was informed that twenty-three years ago a new dock had been built in the King's yard at Plymouth; and when ſhut in, it was found that the water roſe up in the bottom, and looſened the pavement ſimilar to what had happened here; and that no other remedy could be found but new laying the floor with heavy Portland blocks, which method Mr. Barker recommended to the Board to be taken at Ramſgate.—He ſays, "It is propoſed to take up the preſent pavement, and lay down large blocks of ſtone three feet by four, and two feet ſix inches deep; each ſtone to be one ton and a half; and that the maſter maſon is firmly of opinion, the weight of theſe blocks will effectually prevent the water from riſing, and keep the dock dry."

The ſtone merchants at Purbeck on being immediately written to by the ſecretary, returned anſwer, that they were not able to make ſtones to the dimenſions required, but recommended ſtones of a leſs bulk; but as that would introduce more joints and other diſadvantages, Mr. Barker took the maſon's advice, in having them ordered from Portland.

Mr. Barker had the higheſt ſatisfaction in informing the Board, that every year more and more demonſtrated the utility of the harbour, as was manifeſt from the great number

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of shipping that in the course of the last winter had taken shelter in it, and the number of lives preserved. He mentions the following facts; a large Swedish ship ran upon the Goodwin and parted; two Ramsgate boats, at the hazard of their lives, brought the crew, consisting of the captain and twenty men, safe on shore from the wreck *. In December last, eleven ships, all of which had lost their anchors and cables off Dungeness, and several of them otherwise damaged, were brought into Ramsgate by Dover pilots; and the day before Mr. Barker left Ramsgate, a Hamburgh ship ran upon the Goodwin, and the captain and crew deserted her; but she was got off and brought into Ramsgate by two boats, one of Ramsgate and the other of Deal. She came into the bason and delivered her cargo into the storehouse (estimated at betwixt 8 and £9,000), till she repaired.

1787.—The Portland blocks being got with readiness the work of the floor was vigorously pushed during the winter and spring; so that it was completed early in the summer, which being notified to the Board, orders were sent to the master mason to put the work to a trial. In consequence, Mr. Cull's letters of the 3d and 7th August, acquaint the Board, "that agreeably to his orders he had shut in the dock, when to his great concern and surprize, and that of every one present, by the time it was high water, the greatest part of the pavement was disjointed, and hove up; and what was yet more astonishing, nearly 100 feet in length of the north wall was hove up also.

Ramsgate, 22d of August.—Mr. Barker on his visit, taking the affair of the dock into serious consideration; that the harbour being now become very useful to commercial navigation, and that numbers of vessels took shelter therein in winter, for the purpose of repairs; the dock must certainly be not only an useful, but a necessary accommodation; and considering that a large sum of money had been already expended thereon, he judged it proper to engage Mr. Smeaton to come down with Mr. Aubert to examine it, and if possible, to contrive some method to render it useful.

In consequence, Mr. Aubert and Mr. Smeaton arriving, the gates were ordered to be shut at low water; and Messrs. Barker, Aubert, and Smeaton attending the rise of the tide; Mr. Smeaton's report to the Board of trustees contains the following account: "The tide rose that day to the height of thirteen feet four inches upon the apron of the gates of the dock; but before it had risen two feet, it begun to spring through several joints of the stone-floor, which had been laid with solid Portland blocks of two feet and a half in thickness, in fashion of an arch; and which, to all appearance, had originally been sufficiently

* It is proper in this place to remark, that the Ramsgate boats lie constantly afloat, ready to put off at a minute's warning; had this not been the case in that critical moment these unfortunate men would have perished.

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well jointed, and indeed the whole building in point of workmanship, as a piece of masonry, had been done in a very masterly manner.

"As the height of the tide increased upon the apron, the leakage through the joints of the floor gradually formed a greater depth of water upon it, so that when it was high water upon the apron, there was a depth of five feet three inches upon the floor; and we observed, that while the tide was rising, the joints of the side wall, on the north side next the bason, apparently opened, so as in some places to let water through the wall; but in far less quantity than appeared to rise through the floor *. Every thing being left standing when the tide had ebbed, so as to be upon a level with the water within, its depth upon the floor was seven feet two inches."

"The cause of these derangements, was doubtless owing to the pressure of the water under the bottom, endeavouring like a vessel swimming in the water to buoy it upwards; and which, in the circumstance of only eight feet difference of pressure (which in this experiment was the greatest) would amount to 1000 tons upon the area of floor. This power acting upwards, would indeed be the same, whatever material the floor was composed of; but from its construction, as an arch of stone laid very flat, its lateral pressure would, in this case, be much greater than the absolute weight of the wall upon its base; and therefore no wonder that it should shove it outward; and that the effects thereof should be perceived by breaking the joints of the side wall, as has been mentioned."

"He thinks it necessary to state to the Trustees, that this failure has not been owing to bad materials, or bad workmanship, or to taking a method in itself bad, but only become so, by the construction not suiting the situation and soil; for had the ground whereon the dock was founded been a stiff or moderately compact bed of clay, or a rock, either hard or soft, that would not have suffered springs to percolate through its pores; the dock built as it was, or even in its first state, would doubtless have succeeded; but it was the circumstance of there being springs issuing from the area of chalk, on which the floor was laid, that has occasioned the mischief †. And in this respect a wooden floor, according to the original plan, would have been the eligible expedient, as it would have been subject to the upright pressure only, and not to a much greater lateral pressure as in stone arches."

* The Committee's report mentions that the joints of the pavement, or more properly the caping of the wall, had opened one-third of an inch, though the wall itself was fourteen feet thick at its base.

† As I observed a considerable stream of water issuing from under the apron at low water, I ordered this water to be drained therefrom by a chain pump, and found that this spring (which was salt) vented at the rate of 160 barrels per hour, which vent exposed the bottom to the action of the tides waters.

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The Committee's report ſtates that it was Mr. Smeaton's opinion, that the whole bottom of the dock, as alſo the greateſt part of the north wall, are ſo greatly deranged and diſjointed, that it will be neceſſary to take up all the pavement and take down a great part of the north wall; and that, to render the dock ſecure and dry, the bottom muſt be laid upon a different principle, and with a different material; and the wall itſelf made a ſolid piece of maſonry, ten or twelve feet thicker than it is at preſent, for which he was deſired to make the proper deſigns. Accordingly, the men were immediately ordered to begin to take the wall down.

Every thing elſe was found in a way of doing its buſineſs, and anſwering its end; and in attending to the running of the ſluices it was ſeen that the water ran with ſo great a current and body, as to make its way into the ſea, apparently half a mile beyond the mouth of the harbour; but yet Mr. Barker's favourite wiſh of widening the channel under the eaſt pier to a yet greater extent, induced Meſſrs. Barker and Aubert to take the opportunity of conſulting Mr. Smeaton upon that head alſo; and he recommended it to the truſtees, to build another ſluice to the eaſtward of the crane, and by uniting its water with that of the fifth and ſixth, the whole would have an increaſed effect, not only in cleanſing, but in widening that channel.

Meſſrs. Barker and Aubert, attentive to every thing that might conduce to the improvement of the harbour, made uſe alſo of this opportunity in having Mr. Smeaton's opinion upon a point ſo very material and critical, that before the erection of the ſluices, it could not have even been thought of; and that was, that though by the opening of the weſt pier, much good had been done towards quieting the harbour; yet as in very hard gales of north-eaſterly and eaſterly winds, the harbour was ſtill liable to a greater agitation than could be wiſhed, a complete remedy was greatly deſirable. And finding that the ſeamen and pilots of Ramſgate had formed an opinion, that a wall or pier extended out from the eaſt head to 350 or 400 feet in a proper direction, would greatly tend to keep out the ſea, and quiet the harbour; this propoſition was laid before Mr. Smeaton, and he was ſtrongly and clearly of opinion, that ſuch a work would render the outward harbour ſtill more quiet; and that if another ſluice were built it would, together with the good effects from it, before propoſed, countervail any difference that might ariſe from the more weſterly direction of the harbour's mouth, to take in ſilt, which might (not without reaſon) otherwiſe be apprehended.

It appeared to the Committee, that in the courſe of laſt winter, no leſs than ſixty ſail of ſhipping had been ſheltered in the baſon at one time, many of them brought in without anchors and cables, and otherwiſe much damaged, and obliged to unload their cargoes to be

be repaired; and that Mr. Rowe the pilot had actually carried a ſhip of 500 tons directly into the baſon.

The preceding proved to be the laſt report of John Barker Eſquire, who, with great aſſiduity, attention, and perſeverance, had preſided over the execution of the Ramſgate works for nearly twenty-eight years.

SECTION VIII.

THE unanimous choice of Alexander Aubert Eſquire, Chairman, in Autumn 1787; and the ſubſequent tranſactions down to the preſent time.

IN conſequence of Mr. Barker's death, which happened the 1ſt day of November, the truſtees were unanimous in requeſting Alexander Aubert Eſquire, to take the chair; which having been done, the gentlemen obſerved, that from the ſituation of Ramſgate harbour, and the very great uſe it has already been to ſhipping, there was no doubt but it might be made of the utmoſt utility to commercial navigation; but as yet there remained a great deal to be done, and many works to be carried forward to bring it to that ſtate of uſefulneſs and perfection it was capable of; and conſequently it being an affair of great magnitude and importance to the public, it required the conſtant care and attention of a gentleman of abilities and reſpectability, therefore the Board in the ſame unanimous and earneſt manner, requeſted Mr. Aubert to take the lead in the management and direction of the buſineſs and affairs of the harbour, and every thing relative thereto; to which requeſt Mr. Aubert politely aſſented, at the ſame time requeſting the gentlemen to aſſiſt and ſupport him in every meaſure tending to the benefit and public utility of the harbour.

Mr. Aubert being elected chairman of the Truſtees of Ramſgate Harbour, a viſitation was appointed, and the chairman to be attended by the ſecretary and Mr. Smeaton, and they arrived at Ramſgate at Chriſtmas this year.

The firſt object of Mr. Aubert's attention was to render the Harbour perfectly quiet; the utility of it in its preſent ſtate could not be more evidently proved than by the great number of veſſels that had taken ſhelter therein *. It proved a hard gale of wind at eaſt on Chriſtmas day, ſo that Mr. Aubert was himſelf witneſs of the effects thereof, and ſaw that a great degree of agitation prevailed in the outward Harbour, beyond what before he had a conception of; he therefore aſſembled and conſulted ſome of the ableſt and moſt experienced pilots, upon the propoſition mentioned at his laſt attendance at

* - - - - - - - They were informed that above 70 veſſels had been in the harbour at once, ſince they were there in Auguſt laſt, the greateſt part driven in by diſtreſs of weather; ſome of them were of 350 tons.

Ramſgate,

Ramſgate, and they all agreed that there was an abſolute neceſſity for ſuch a work being carried into execution; and that if a pier of 350 or 400 feet were carried out in a proper direction, it would not only keep out the heavy ſea that now tumbled in in hard gales of wind, and make the Harbour more ſafe and quiet, but that the coming into the Harbour would in reality be more ſafe and eaſy. For they obſerved, that at and near high water the tide runs briſkly from the weſtward acroſs the Harbour's mouth: [illegible] obliging the ſhips and veſſels that intend to make the Harbour to come down from the weſtward; if a pier were extended in a proper direction, they would then come in right along with the tide, and with more facility than at preſent. The only thing that appeared to them in the ſhape of a doubt or a difficulty, was, whether the Harbour could be as effectually cleanſed from ſilt, that is continually brought in, as it now is *? To which Mr. Smeaton made anſwer, that before the eſtabliſhment of the baſon and ſluices, ſuch a work could not have been thought of; but there was now ſo great a power of backwater, which could be increaſed as already intimated, if there were found occaſion; that if the work propoſed would not leſſen the facility of the entry, which in their judgement it would not, he would be anſwerable to keep the Harbour to as great a depth, and as clear of ſilt as it now is.

Mr. Aubert concluded his report to the Board, with obſerving, "that the works of Ramſgate Harbour have, for a ſeries of years, been carried on without the aſſiſtance or direction of any engineer, or even a reſident ſurveyor †, one or two occaſional conſultations excepted; and in thoſe particular caſes the plans of the engineer were only in part adopted. It therefore ſeemed to him, that in works of this nature and magnitude it was of great importance to have an able and ſkilful engineer; who uniting the powers of mechaniſm with a thorough knowledge of the materials, ſo as to apply them to the beſt advantage, might rationally be expected to be the means of ſaving many thouſand pounds, and give durability to the works; and is conſequently deſirous of being guided by ſome profeſſional man in that line."

"Upon theſe conſiderations Mr. Aubert has no doubt but the Board ſee the neceſſity of employing conſtantly ſome able engineer in the deſign and conſtruction of their future works; and therefore as Mr. Smeaton has already been employed occaſionally by the truſtees, and by ſeveral of the executive Boards under government, and is well known to ſtand high in profeſſional character, Mr. Aubert is perſuaded the Board will approve

* Mr. Smeaton's ſketch of an advanced pier was then laid before them.

† Mr. Etheridge was the only perſon who had been employed in this capacity, except occaſionally, and whoſe ſervice terminated with the year 1753.

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of his being requeſted to take upon him the guidance and reſponſibility of the engineering part of the works. But although Mr. Smeaton may be induced to go down to Ramſgate periodically, and to furniſh every neceſſary plan, as he cannot upon any conſideration be reſident upon the ſpot; it appears neceſſary, that he may be made reſponſible for the perfect execution of his plans, that he ſhould have ſome experienced reſident ſurveyor, in whom [illegible] confidence; and ſuch a one, in caſe the Board ſhould think proper to employ him as their reſident ſurveyor, he is enabled to recommend in the perſon of Mr. John Gwyn, who has been employed twenty-ſeven years under Mr. Smeaton's direction as deputy ſurveyor; and who during that whole period has given him the greateſt ſatisfaction in the execution of ſeveral capital works.*"

In conſequence of theſe recommendations Mr. Smeaton was unanimouſly choſen engineer, and Mr. Gwyn reſident ſurveyor.

Being now entered upon my office of engineer of Ramſgate Harbour, it may be ſuppoſed that in carrying forward the account of the tranſactions thereof, I am no longer under the neceſſity of drawing my materials chiefly from written documents, but that I may in my own perſon carry on the narrative; and this I am the more inclined to do, as I can ſtate my own remarks on perſons and things with much greater brevity.

1788.—In April I attended the chairman on his firſt viſitation, accompanied by the ſecretary. At this time the whole of the north wall of the dock was taken down and the area cleared, and a conſiderable progreſs made with the timber new floor. Upon this viſit the chairman fully opened and explained his intentions to us, the principal officers and artificers; viz. That though the re-conſtruction of the dock was with him a great object; as when completed it would be of very great utility and accommodation to thoſe who are driven into the harbour by ſtreſs of weather; yet he could not conſider it as the primary object to which we ought to bend all our powers. It appeared to him, that the rendering the harbour a place of quiet and ſafety for the ſhipping, was to be the thing aimed at, and endeavoured to be atttained, in preference of all other conſiderations. That therefore the works of the propoſed advanced pier were to be puſhed, at the ſame time that thoſe of the dock might be carried on whenever it could be done without retarding the primary object; and with this view he ordered an additional number of workmen.

* Mr. Aubert ſpecified the works executed by Mr. Gwyn, under Mr. Smeaton; viz. the Calder Navigation, the Bridge of Perth, the Harbour of Portpatrick, the Pier of Aberdeen, the Pier and Harbour of Cromartie, and the Drawbridge of Hull.

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On this occasion I took the liberty to recommend, that myself accompanied by the two principal artificers, Messrs. Gwyn and Cull, should visit the stone quarries of Purbeck and Portland, to see and examine their present state and produce; and also more especially to examine the limestone quarries of Lyme in Dorsetshire, as I had been informed that the true Lyas limestone was to be had there; and which, if so, was likely to prove a valuable acquisition to these works *. This journey having been made, in consequence, the use of this valuable lime has been established here and continued ever since.

The chairman on examination found that the bason was kept clear of silt, by the use of the horse-dredges or drugs, and the channel under the east pier improved; there being now good eighteen feet water at a middling tide from the harbour's mouth, up to the stairs nearest the town, and the sullages of the whole harbour visibly decreased since Christmas, by the frequent running of the sluices.

Our second visit was in June, at which time the labourers were diligently employed in getting up a large quantity of stones that had been thrown in to secure the pier head, as mentioned in the year 1774, which it now appeared were necessary to be removed in order to clear the foundation for the advanced pier. But as it seemed dubious whether they could all be got up in nine and ten feet water by the usual method of tongs from the barges; this occasioned me to turn my thoughts upon a diving machine I had formerly made use of with success in doing works considerably under water.

I had scarcely returned from this visitation before a requisition came to desire the expedient I had mentioned might be got ready, which was done with such expedition, that I set forward for Ramsgate the 6th July in order to put it in use; and the 12th left Ramsgate, after a full trial of the diving chest, and the certainty of success †.

With this machine, which enabled the workmen (or divers) therein to stay under water any length of time at pleasure, that is when the wind was moderate, that the

* I did not at this time imagine this lime had ever been used in those works, as appears to have been done; but without understanding its merits, was now grown into disuse.

† Instead of the usual form of a bell or of a conical tub of wood sunk by weights (externally applied), this for convenience, was a square chest of cast iron; which being 50 cwt. was heavy enough to sink itself; and being $4\frac{1}{2}$ feet in height, $4\frac{1}{2}$ feet in length, and three feet wide, afforded room sufficient for two men at a time to work under it. But it was peculiar to this machine, that the men therein were supplied with a constant influx of fresh air, without any attention of theirs; that necessary article being amply supplied by a forcing air pump, in a boat upon the water's surface.

boats

boats could attend, in the course of that and part of the following month the foundation was cleared; * and the tools for levelling of the ground, the same that were originally invented and applied by the late ingenious Mr. Etheridge, were now put in use, under the management of Mr. Cull the master mason, who had formerly been employed in that part of the business; it being the Chairman's wish, as best for the work, that every thing should go on in the same method as originally practised.

Soon after our return from the June visitation, Mr. Aubert having had the misfortune to break his leg by a fall off his horse, could not attend the third visitation of this season; but I attended the secretary to Ramsgate; and the third of September we were present at the sinking of the first caisson of the advanced pier, when every thing was carried on with regularity and satisfaction; as much additional stone being built therein that tide, as would prevent its being afterwards moved by the sea; and the next day it was got up to its height; that is, above the low water mark of ordinary neap tides.

The piling of the dock's bottom was also now considerably advanced, and several of the double beams of the floor were laid, and every thing going on to satisfaction.

The Chairman being recovered, attended the fourth and last visitation of this year. His report thereon bears date 15th November 1788. It notices that the getting up of the stones (some of them in $12\frac{1}{2}$ feet under water), which from the circumstances had become a work of absolute necessity, had been successfully performed; and also the sinking of the caissons of which he had the pleasure to find four in their places, and built up to their proper neap tide low water height. He also found that the fifth and sixth caissons with their materials were all in readiness; yet observing the effects that the sea had had in a gale of wind the night preceding, it having torn away one of the wooden sides of the fourth caisson, he considered that the season was far advanced; and consulting the engineer and principal officers, it was unanimously agreed, that it would be imprudent to attempt to sink any more caissons at present, but rather to do what would be likely to secure what had been done as soon as possible; and then postpone the further progress till the spring.

The floor of the dock being in a state of forwardness, above half of the ground timbers being laid, the Chairman ordered that the men should be employed in that work as much

* It was computed that about 160 tons of stones had been got up in clearing the foundation; and that about 100 tons thereof had been raised by the diving machine, many of above a ton each; but the want of the machine would doubtless have been the loss of the season.

as

as they could be during the winter feafon ; but that the primary object might be kept in view, Mr. Aubert recommended, that carpenters be employed in preparing and framing more caiffons ; and that a proportionable number of mafons be preparing the ftone for the fame, fo that the works of the advanced pier might commence again, and be carried on with vigour, as early as weather would permit the next fpring.

The Chairman further reported to the Board as follows : " that there is always a light put upon the head of the weft pier at night, as a direction and guide for veffels and boats, coming in and going out of the harbour ; and alfo that a flag is hoifted on the north weft cliff, when the water rifes to ten feet at the gates of the bafon ; and continues flying (in the day time) till the ebb reduces it below that depth, as a fignal for veffels in the Downs ; but as bad weather and gales of wind naturally happen in the night, as well as in the day, and confequently fhips and veffels may meet with accidents from ftrefs of weather, or from other incidental caufes, and be defirous of running for the harbour for fhelter, fuch veffels perhaps not knowing the depth of water in it, are reftrained from attempting to make for the harbour, when they might do it ; Mr. Aubert therefore thought it adviseable to call in fome of the moft experienced pilots ; who unanimoufly agreed, that a double light always put upon the head of the weft pier, in the night, when there fhall be ten feet water at the gates of the bafon ; the additional light to be elevated about eight or ten feet above the prefent light, and fufficiently ftrong and luminous to be feen in the Downs, would be of great utility, as the double light would be a fignal, denoting to mafters of veffels that they might make for, and enter the harbour with fafety."

Mr. Aubert (whenever the tides ferved) directed the water to be fhut in the bafon, and the fluices to be run ; and had the fatisfaction to obferve, that they continued to operate with their ufual force and power ; as he perceived the water, with a rapid and ftrong current, carried the filt out a great way beyond the tranfport buoy : and that by working the dredges, and running the fluices occafionally at the fpring tides, the bafon is kept clear of fand. He had likewife the pleafure to inform the Board, " that the channel under the eaft pier is confiderably widened, that it can receive and fhelter a great number of fhips of large tonnage, that the depth of water is confiderably increafed, and the whole harbour is in fo improving a ftate, that there is the greateft probability in the courfe of a few years, it will become a place of the greateft confequence to the commercial navigation of this kingdom."

" Mr. Aubert embraced the opportunity of again affembling and afking the pilots their opinion refpecting the advanced pier, and they profeffed the fame belief of its beneficial confequences,

confequences, in quieting the harbour ; they likewife obferved, " that the prefent ufual and fafeft track, for veffels making for the harbour, is to come in from the weftward, and that when the advanced pier is completed, veffels will then (as now) come in right before the tide ; and in all probability, with more eafe and fafety."

1789.—The Chairman's firft vifitation to Ramfgate this year, was in March, and we arrived there the 12th. The 14th the fheet piling inclofing the circumference of the dock floor, was clofed in ; all the beams having been previoufly laid.

With refpect to the works of the advanced pier, the caiffons were in fufficient forwardnefs, but it was yet too early in the feafon to attempt any thing at that : it had been built upon and fecured, fo that no damage had happened to it during the winter. The Chairman therefore contented himfelf with examining the ftate of the works, and giving the neceffary directions, that every thing might be in forwardnefs as foon as the feafon became favourable.

The fecond vifitation was the latter end of May. We then found the floor of the dock laid, and the mafon-work begun : but that Mr. Gwyn the deputy furveyor, being afflicted with an abfcefs, was unable to attend at the yard *.

The works of the advanced pier were now going on, and four caiffons had been funk this year (making eight in the whole), and others forwarding. Upon this journey we vifited and landed upon the Goodwin Sands, to have a view of them and examine their nature ; and found that though of the nature of a quick fand, clean and unconnected, yet the particles laid fo clofe, that it was difficult to work a pointed iron bar into the mafs, more than to the depth of fix or feven feet.

On this vifitation I took feveral levels of the relative heights of different parts of the works compared with the bottom ; alfo, particularly examined the lighthoufe, as relative to the Chairman's laft propofition to the Board.

In Auguft the truftees affembled at Ramfgate, on a general annual vifitation, and the 24th, reported as follows :

" Your Committee proceeding in their furvey, ordered the water to be fhut up in the bafon, and have the pleafure to inform the Board, that by running the fluices three or

* Of this he died in the courfe of the next month ; a real lofs to the public, as well as lamented by his family and friends.

or four times at spring tides, and working the horse drags, the bason is kept clear of sullage; your Committee likewise observed, that the channel under the east pier is considerably wider, and in its present state capable of receiving a number of ships of 500 tons and upwards; and it is acknowledged by all persons acquainted with the harbour, that it has been wonderfully improved within a few years past, as in the most useful parts of the harbour there is an increase of between five and six feet water; and whoever contemplates it in its present state, and peruses the evidence given at the bar of the House of Commons, prior to the passing of the Act of Parliament, and also the preamble to the Act, will be convinced that Ramsgate Harbour now exceeds the hopes ever entertained by its projectors and friends; or, that the legislature had any idea of, at the passing the Act, which supposed it might be made a receptacle for shipping of and under 300 tons, but could not imagine it ever would be capable of receiving ships of much larger burthen. That the harbour is of great importance to commercial navigation, the well attested documents of the office sufficiently prove; videlicet, That the harbour (under Providence) has already been the means of saving property to the amount of between three and four millions sterling, and between eight and nine thousand valuable lives, to their friends and society; yet notwithstanding the truth of these striking facts, the present useful state of the harbour, through prejudice or want of proper information, not being known to the public as it ought to be, your Committee think it necessary to recommend, that Mr. Smeaton your engineer be desired to draw up a proper account of the harbour in its present improved state, to be published at a convenient time."

The walls of the dock were then up seven or eight courses high; the whole design of it was fully apparent to the Committee.

The seventh caisson was now sunk, while the Committee were there; and every thing being in a state of going on successfully and satisfactorily, the Committee signified their wish to see the operation of the diving machine or bell (as in conformity to custom, it had now acquired that name,) for it appeared to the Committee, that by means hereof it would be very practicable at any time to examine the state of the foundations that had been laid a course of years; and particularly, whether the timber bottoms of the caissons, that laid under the piers, and immediately upon the chalk, had not greatly suffered by the worm? and further, that by the same means, it would be practicable to make in future any repairs to the foundations that might, on account of the above or any other cause, be found necessary.

On

On this occasion, I had the honour to attend the Chairman down to the bottom of the sea, upon which we could stand, and work dry. In this situation the Chairman finding himself perfectly at his ease, and very comfortable, staid full three quarters of an hour. We found that the ground work, that is the bottoms of the caissons, was now so deeply buried in sand and silt, that it would be a work of considerable labour to rid it out and clean it; and as this is doubtless the best defence against the worm, he concluded it inexpedient to attempt to disturb it: having fully satisfied himself of the practicability of staying any length of time, and of performing any kind of work, that the bounds thereof admitted, with a capability of removal almost at pleasure, we gave the signal for ascending, and were received with great joy by our friends, whom we found surrounding us in boats, and who by this time were beginning to be apprehensive that something might have happened to us.

This visitation I took an exact plan of the west pier head, to enable me to make out a design for a lighthouse for the approbation of the Board, for erecting a double light upon that head.

The Chairman's last visitation of the year 1789, was November 7th. At this time, though the weather had lately been but indifferent, yet eight caissons had been sunk, and fixed this year; which, with the four sunk the last year, completed twelve in two years, as we originally had in view. The Chairman consulting the engineer and principal officers, considered that those twelve caissons would need to be secured; and that the best way to do this was to build the superstructure upon them, with all possible diligence. And furthermore, that it would be eligible, rather than completing any particular part, to go on with the whole length, which being now 120 feet, that is, nearly one-third of the proposed advanced pier, if weather permitted, that it could be got up to high water mark by Christmas; this would be sufficient to demonstrate the effect that was likely to be produced, and would be of great service, in affording an addition of shelter to the shipping the ensuing winter; in short, it would give us an experimental proof of the good or ill that was likely to arise from the farther prosecution of this work; and the harbour having been sounded, nothing so far appeared but what was in favour.

It also had happened in the late autumnal winds, that the break-water or jettee in the external angle of the east pier with the land, had been washed down and totally demolished. This was a work that had been erected several years before, chiefly of old ship timber, by way of experiment, for the defence of the pier, and the establishments there. This having, with frequent repairs, answered the end ever since, it appeared

therefore

therefore very defirable and neceffary to be rebuilt. This being the cafe, the Chairman thought it ultimately for the greateft benefit to the harbour, to rebuild it with ftone, and in the moft fubftantial manner, being greatly expofed: and I was ordered to prepare a proper defign for a ftone break-water or bulwark, for the approbation of the Board. Here therefore were two objects that wanted to be profecuted both at once; and both with our whole force; but as the break-water could not be more than totally deftroyed, which it then was, the Chairman judged it of the moft importance, both in point of fafety and ufe, to carry on the advanced pier till it was got to its height; which was done in the courfe of this year.

1790. This year commenced with the building of the break-water. In January many heavy gales at Weft came on, which of courfe detained the fhipping in the Downs, many of them therefore fought fhelter in Ramfgate harbour, and found it in a degree never experienced before; fo that in the courfe of this month, there were in it at one time 160 fail, the greateft part of which lay in the bafon, and there was room in the harbour for many more. This affemblage of fhipping afforded a fpectacle fo new, that the people all round the country came to fee it.

The chairman's firft vifitation this year was the beginning of March; but the getting up of the advanced pier, and after that of the break-water, having totally occupied the mafons, the dock was obliged to remain as it had been left the laft fpring. The break-water was now in a ftate of proceeding very vigoroufly; but it being too early in the feafon for any thing to be done at the advanced pier, the chairman could only give the neceffary orders, that nothing might hinder the proceedings when the feafon was more advanced.

The beginning of April a very hard gale of wind happened at E. S. E. and the capping courfe of the break-water not being quite clofed in, the violence of the fea wafhed ftones of one ton and a half out of their places, though every thing that had been completely fixed, ftood faft. This, however, fhewed us that we had not beftowed on this work more folidity than neceffary, as fome had been induced to imagine. The violence of the fea alfo fell fo heavy upon the advanced pier, that the extreme unfinifhed termination became underwafhed, and caufed a fettlement of the exterior angle, which immediately obliged Mr. Cull to guard it with rough ftones, in the manner the original pier-head had been before the removal thereof; and likewife to take fome of it down, in order to ftraighten the wall.

Thurfday

Thurfday, 27th May, the Chairman arrived at Ramfgate, upon his fecond vifitation; and then found the break-water completed; the damage at the advanced pier rectified; and two caiffons, viz. the 13th and 14th ready to be put down, and which were funk while we were there. We faw the fluices run; examined the channel, and found it without any fenfible alteration from the prolongation of the advanced pier.

Thurfday, the 12th Auguft, the general vifitation of truftees took place, at which time the eighteenth caiffon was funk, the works examined, the fluices run, and every thing found fatisfactory.

Six caiffons having been laid this year, and finding ourfelves too late in the laft feafon, by laying eight, it was thought beft by the Committee to terminate the work of this feafon, as to the laying down of caiffons; and to employ the remainder of it in getting the pier built up, fo that every part might be feafoned before the winter and heavy gales come on: and as there would now be full 180 feet of the advanced pier laid, this, when raifed to its height, would be an effectual trial of the utility, effect, and validity of this work.

The Committee had the fatisfaction to obferve a very vifible alteration in the width of the channel under the eaft pier, which had been chiefly brought about by the running of the fluices, during the crowd of veffels in the harbour in January laft.

Upon the Chairman's fourth vifitation of this year, we arrived at Ramfgate the 21ft October, and then found the prefent ftretch of advanced pier in general up to high water mark.—During our ftay here, we had a hard gale of wind at eaft, for three days together; and then had the great fatisfaction to find the harbour, which when the wind was at that point ufed to be much agitated, to be moft remarkably ftill and quiet; fo great a change in this refpect could have fcarcely been expected, till the pier was carried out to its full length, of which what was now done was fomewhat more than half. On this occafion we thought it neceffary to compare the harbour-mafter's foundings, taken in May laft, and alfo the prefent month, with our own now taken in his prefence; and on comparing them, had the fatisfaction to find the channel of the harbour, notwithftanding the advancement of the pier, to be in an improving ftate in depth as well as in width.

The

The present State of Ramsgate Harbour.

THE operation of the sluices, as has been described, has gradually cleared out a broad space or channel through the middle of the outward harbour, from the gates to the pier heads; and the bottom lying upon a gentle slope, makes above six feet more water in that material part now, than in the year 1774, so that vessels drawing from ten to eleven feet water, can go into the bason in neap tides; and in spring tides those drawing from fourteen to fifteen feet.

Under the curve of the east pier, the sluices have now cleared a channel capable of taking two ships abreast, with clearance for passage, where at neap tides there is from sixteen to seventeen feet water, and at spring tides from twenty to twenty-one feet, and often twenty-two; so that not only vessels of 300 tons, the primary object of this harbour, may come into it in all tides; but at spring tides as large ships as are ordinarily employed in the merchants service. It is here in reality no material objection, that a vessel cannot come in from the Downs at low water; because she is not in distress there till the tide is risen to that point of height that it begins to run northward, and then it has been amply shewn, that there is always water to go into Ramsgate; and that with every wind whereby she can be annoyed in the Downs, she will be right before it into Ramsgate; and every wind that will be fair for ships to proceed upon their voyages from the Downs, will be also fair for their sailing from Ramsgate.

If therefore it be really eligible to have a harbour for the reception of ships in distress from the Downs, it must be upon the flat shore of the Isle of Thanet; and no place has yet been pointed out so proper as Ramsgate.

It probably will be thought by many who cursorily view the place, and are not fully apprized of the requisites of an artificial harbour, to be a defect, that this harbour is not entirely covered with water all over its area at low water; but the bank is really of the greatest utility, as will appear when the pilot's representation above noticed is fully considered. However, notwithstanding that for the reasons already mentioned none of the sluices have been brought to play upon the bank, yet it has in reality so much wasted, that the highest part of what now remains is lower by five feet than the middle of the harbour was in

in 1774; and indeed it is so far wasted and wasting, that probably it will not be many years before expedients will be found necessary to preserve it. There have already been complaints, that it is grown so low, that at neap tides the vessels cannot get their ballast therefrom; and the expedient of filling barges in readiness has been ordered by the trustees for a remedy of that defect. At a spring tide there is now thirteen feet water over it, so that a number of the smaller vessels may occasionally lie upon it.

Besides the completion of the advanced pier and works now in hand, there is obviously a number of articles of considerable expense, that will greatly tend to improve, strengthen, and confirm the whole work; and which may very well be expected, after the various councils, turns of fortune, and changes this work has undergone, are considered. And after all, a harbour that must subsist by the artificial power of sluices, must be subject to a continual expense, and great care to keep every thing in repair and in order; but when all those things are duly, properly, and attentively performed, I doubt not to see the time when it will be said, notwithstanding its misfortunes, and the obloquy that has been occasionally cast upon it, to be a work worthy of the expense it has incurred, at least by the attempts to recover it from the condition it was in in the beginning of the year 1779. I will conclude with saying, that according to my information, 130 sail of vessels were at one time in the harbour, driven in by stress of weather in the late winds of January 1791, among which were four West Indiamen richly laden, from 350 to 500 tons; and if we are to suppose that the whole or the greatest part of these 130 vessels would have been riding in the Downs during this stormy weather, we need not be at a loss to judge what a number of additional dangers and difficulties would have been in the way of those which actually did ride there. I understand that the number of vessels in the Downs at one time has rarely ever exceeded 300 sail; but in the bad weather in the beginning of the year 1790, and in the present year, the Downs were in a great degree cleared, there being in reality few ships left riding in them.

A List of the number of Ships and Vessels that have taken shelter in Ramsgate Harbour in stormy weather:

In 1780	-	29	In 1786	-	238
1781	-	56	1787	-	247
1782	-	140	1788	-	172
1783	-	149	1789	-	320
1784	-	159	1790	-	387
1785	-	213			

Among the above were several from 300 to 500 Tons burthen, and upwards.

Within

Within the last seventeen months upwards of six hundred sail of ships and vessels have taken shelter in the harbour, of which above three hundred were bound to and from the port of London.

Evidence can be produced, that the harbour has been this winter the means of saving a great many ships and vessels, and property to the amount of between two and three hundred thousand pounds, with a great number of valuable lives, which otherwise would have been driven upon the flats and rocks, and in all probability lost.

As an addition to this Report I have the pleasure of informing the public, that, on the 17th July 1791, at a high spring tide, the new dry dock built in the bason for repairing ships was tried in the presence of the chairman, for the first time since it was found necessary to build it with a timber floor, which is of a new and peculiar construction, on account of the springs from the chalk rising so powerfully under it as to force up the stone floor with which it had before been twice tried. The experiment answered in the completest manner; the dock remaining perfectly dry till low water, when the sluices of the bason were opened for scouring the harbour, so that this very desirable object, that has been so much despaired of, is now fully obtained, and must prove of great utility to the public.

SANDWICH HAVEN.

The REPORT of JOHN SMEATON, Civil Engineer, upon the State of Sandwich Haven.

To the Mayor and Magistrates of Sandwich.

GENTLEMEN,

THAT according to historical accounts Sandwich was once a famous and flourishing sea-port, and that the Isle of Thanet was completely surrounded with navigable water, there is not the least reason to question; for the change from that to its present state, without supposing any particular convulsion of nature, or neglect of particular persons, is conformable to the regular change that is constantly experienced in all similar situations; the mud wherewith the sea-water is always charged in a greater or a less degree, being ready to subside and fix wherever it can meet with a place of rest. The great cause whereby it is kept suspended, is the movement and agitation of the waters that contain it. Wherever the quantity and agitation of the water are too little, or the quantity of mud is too great to be kept in motion by the agitating powers, its natural tendency to rest will operate; and the effects of want of motion increasing in proportion to the progress made, a more rapid change ensues towards the completion of nature's operation, than in the more early stages. Every creek, inlet and bay, that has not a sufficiency of fresh water rivers to keep it open by being discharged through it, has a tendency to become land. While such creek or bay remains deep, a quantity of tide's water flowing in and out twice a day, tends to keep the mud in agitation and from settling; but as the tide of ebb is naturally weaker than the flood, the ebb will not carry out all that the flood has brought in; and when the deposition is so far advanced as to contract the breadth of the water, and render it to a certain degree shallow, the quantity of water flowing in and out being lessened, its power is weakened. The natural means whereby an inlet is kept open, is the discharge of a fresh water river through it, which opposing the influx of the tide, and adding to the force of its ebb, will always maintain a certain channel in proportion to the quantity of land-water that requires to be discharged. The tendency of nature therefore is to contract the channel to such a size, that the natural power of the stream can just maintain it; and in this state the wide extended arm of the sea, anciently flowing by Sandwich, and up the general vallies, as now called, seems to have been at the period that the new cut at Stonar was projected and executed.

A river ſuch as the Stour, is by no means adequate to keep open ſo large an arm of the ſea as that through which it flowed in former ages; and the powers of its current having become conſiderably weakened by the meandring courſe it took, (which in effect leſſens its declivity) the difficulties of draining the marſhes and adjacent low grounds became greater in proportion as the depth and width of its channel grew more contracted. Thus, while ſo obvious a remedy preſented itſelf as the turning of the river through the narrow neck of land at Stonar, where, in the ſpace of a furlong, there was a fall of more than a fathom; it is not to be wondered that the landed intereſt in the level, was eagerly wiſhing to ſeize the apparent advantage, and indeed ſo happy and eaſy an expedient rarely occurs in ſubjects of drainage. The late Mr. Yeoman in his report, ſpeaks of having had experience of other rivers under the ſame circumſtances; for my part I have ſeen many rivers; but the Stour in this reſpect ſtands alone. Could Sandwich have been as eaſily moved to Stonar, as the Stour carried through this cut, every thing would have been well on all ſides; but notwithſtanding the aſſurances of Mr. Yeoman, it certainly was contrary to the experience of us all, to ſuppoſe that the running of the height of the flood waters by another channel ſhould tend to improve the harbour of Sandwich; unleſs he meant that part of the Stour that lies below the new cut at Stonar, to the ſea, as being the harbour of Sandwich, of ſo much importance to that town. The thing is however now fixed; and under certain regulations by an Act of Parliament, which cannot be deviated from by either intereſt without the conſent of the other. But it appears to me that there is nothing to hinder a different mode of operation by conſent of parties; if it can be made appear, that they both will be bettered by the change; and this I will now endeavour to point out.

It is the great land floods proceeding from great downfalls of rain, or diſſolution of ſnow, or both conjointly, that is the great operative cauſe in clearing the channels of rivers to ſea; and this chiefly when the tide is out; and moſt of all when they happen at the low ebb of a ſpring tide: at ſuch a time more work is done in a few hours than could be done in months by a leiſurely or moderate reflow; this may, as the engineers affect to term it, grind away a little of the mud, ſand, and ſilt; but the former tears it away with violence. A gentle reflow, experience evidently ſhews, diſturbs not a particle of ſand or mud; on the contrary, if the preceding tide of flood has had power to bring in a quantity of ſilt along with it, ſuch a reflow will give it leave quietly to ſubſide; and where nothing is done towards its removal in one tide, no number of repetitions will amount to any thing. It ſeems therefore to little purpoſe for the Harbour of Sandwich, I mean that part of it that is contiguous to the town, when the top waters are drawn off through the flood gates of Stonar, to leave the dribblings of the floods and ordinary current of the river, to go quietly round by the way of Sandwich.

The

The work being now executed is not, as before the paſſing of the Act, a matter of ſpeculation; the effects may be evidently ſeen and with more certainty judged of. I muſt take for granted that the ſtandard mark was fixed as the law directs, at the medium of nine feet above the bed of the river at the head of the cut: let any one now ſound the depth of it for ſome ſpace below the head of the cut and he will perceive how miſerably it is here diminiſhed, both in depth and width. This evidently ſhews how much the water has loſt of its cleanſing and ſcouring power, ſince the paſſage of the top waters have been diverted. On the other hand let the channel of the Stour be viewed above the head of the new cut, he will ſoon perceive how greatly it is augmented; how ſtriking the contraſt! all this in favour of the drainage.

For my own part I am profeſſionally as great a friend to drainage as to navigation; and therefore if I can ſhew, in conſequence of what has occurred to me from the view I have taken, how the drainage may be very materially improved, even beyond the advantages already gained, by means that will improve the navigation alſo; and that without any new charge, I ſhall be doing an evident ſervice to both.

I have always underſtood, and believe it to be true, that the flooding of low grounds in the vallies of rivers is an advantage to the grounds, provided it is done or happens at ſuitable ſeaſons of the year; for the freſh waters that come down from the high grounds in floods, conſtantly bring with them a quantity of ſoil enriched with the manure that waſhes down from the higher country, which being depoſited upon the ſurface of the low lands, very greatly improves their fertility. It is the misfortune of low lands which are not in a ſtate of perfect and ready drainage, that the water when brought upon them by the winter rains is apt to lie upon them ſo long in the cold ſeaſon of the year, that it greatly damages the roots of the uſeful vegetables (which in general are not aquatics), ſo that the occupiers of theſe lands, loſing much more by the continuance of the water upon them than they gain by the depoſition, generally reckon and imagine they never can get them dry too ſoon. Now, ſuppoſe at the beginning of a flood, if the waters were kept upon the ſurface of the vallies for a fortnight, they would be fertilized thereby, provided they were run off more ſpeedily afterwards than they uſed to be. The height or depth of the water upon the land is not what does the damage, but the contrary, the injury ariſes from its long continuance at a ſmall depth; and in caſes of difficult drainage the difficulty has not been to get rid of the top waters, which by their height have a greater declivity to the ſea; but the bottom waters, by the riddance of which the ground is made competently dry and fitted for the purpoſes of agriculture.

S 2 Imagine

Imagine now in the winter months; ſuppoſe, November, December, January, February, and a part of March, that inſtead of drawing the gates when the water was juſt above the mark after a dry ſeaſon, they were to remain ſhut for a certain number, ſuppoſe for three or four days, that the water might completely overflow the meadows and take its ancient courſe; that then the gates were drawn, and without being reſtricted to wait for an hour's ebb on the haven ſide, and then to run only for five hours each tide; they were to run them as ſoon and as long as the land flood water would override the tide, for the ſpace of four tides running, then let them remain ſhut for four tides, and four tides run as before; and ſo alternately, four tides and four tides till the flood was run off, and the water never roſe in the time ſhut to the ſtandard mark.

In this way it is very certain that not only more water would run through the flood gates in a given number of days, than can do now in five hours each tide; but by drawing lower in conſequence of a continued draft, the deſcent of the water from the meadows would be more quick and effectual, and particularly ſo in the decline of floods. On the other hand the greater abundance of top waters that would this way be forced to paſs Sandwich Bridge, would much more effectually tend to keep the whole channel of the Stour open, in its long meandring courſe from the head to the tail of the new cut, than it can now do, when it is never ſuffered to have its full effect, owing to the conſtant diverſion of a great part of it by the new cut. By this means a ſcouring power would act at intervals through Sandwich Harbour, of much more conſequence for the reaſons given, than the weakened one it can now have; and which, combined with the advantage that the lower part of the haven, from the tail of the cut to the ſea, muſt neceſſarily receive from the flood gates, appears to me ſufficient to keep the harbour of Sandwich in as good order, as it has been known in the memory of man; provided a little help from the hedge-hog and ſpade be given in ſome particular places.

The harbour of Sandwich, properly ſo called, I find is complained of rather on account of its growing narrower than ſhallower. The contraction of its ſection is a natural conſequence, of the loſs of the force of the top waters of the land floods; but I think it is particularly fortunate that the contraction has rather been in width than in depth. The expedient therefore that I have propoſed will, together with the means already uſed, in all likelihood recover the former width, or at leaſt prevent a further contraction.

When a freſh water river makes its way to ſea through the looſe ſand and ſilt that the ſea has originally depoſited, its courſe is continually varying, as there is nothing ſtable to fix it; for when by any accident it gets into a curve out of a ſtraight line, the water by

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its ſuperior action on the concave ſide of the curve, tends to make it more curved. To attempt to cut off the points by the ſpade is an endleſs and therefore an uſeleſs work. Nor can the matter be mended by jettees, becauſe theſe will make curves where there were none before. All that can be done to the purpoſe in this caſe, is to alter the perches and buoys conformably; ſo as to point out the channel.

Upon this view I found not only the outward haven, but the harbour* of Sandwich in reaſonable good order; indeed in better than I could have expected, conſidering the natural difficulties to its ſubſiſtence; and eſpecially ſince the total ſubtraction of the top floods from the harbour; which affords an inſtance what a little help will do when properly and ſeaſonably applied, as I underſtand the hedge-hog has been made a conſiderable uſe of; for when the water runs with a briſk current, a great deal of ſand and ſilt will be carried by it down ſtream to ſeaward.

The river Stour above the limits of Sandwich Harbour grows ſenſibly more and more contracted and obſtructed with weeds, till we arrive at the head of the new cut. This diſtrict in ſeveral places wants the ſpade as well as the hedge-hog, which I alſo underſtand to be here uſed by the Commiſſioners of ſewers; and it appears to me that every year this evil will increaſe, unleſs prevented by the different mode of running the flood gates I have recommended, and which will be by far the cheapeſt expedient.

The Commiſſioners of ſewers in this way, will alſo be relieved from the neceſſity of maintaining the new cut at the width of 40 feet; the fulfilling of which condition I expect will otherwiſe occaſion a very conſiderable expenſe; as the operation of the flood gates ſeems likely to widen it apace.

I ſhall conclude with obſerving, that what I have recommended being a matter of ſtipulation, may be tried for a year or two certain, till the effect of it is ſeen; and then a more ſolemn engagement entered into, as the effect of ſuch experience ſhall evince.

Grays Inn,
15th *Auguſt* 1789.

* This diſtinction ſeems neceſſary to avoid ambiguity; the haven being ſuppoſed that part between the tail of the new cut and the ſea.

DOVER HARBOUR.

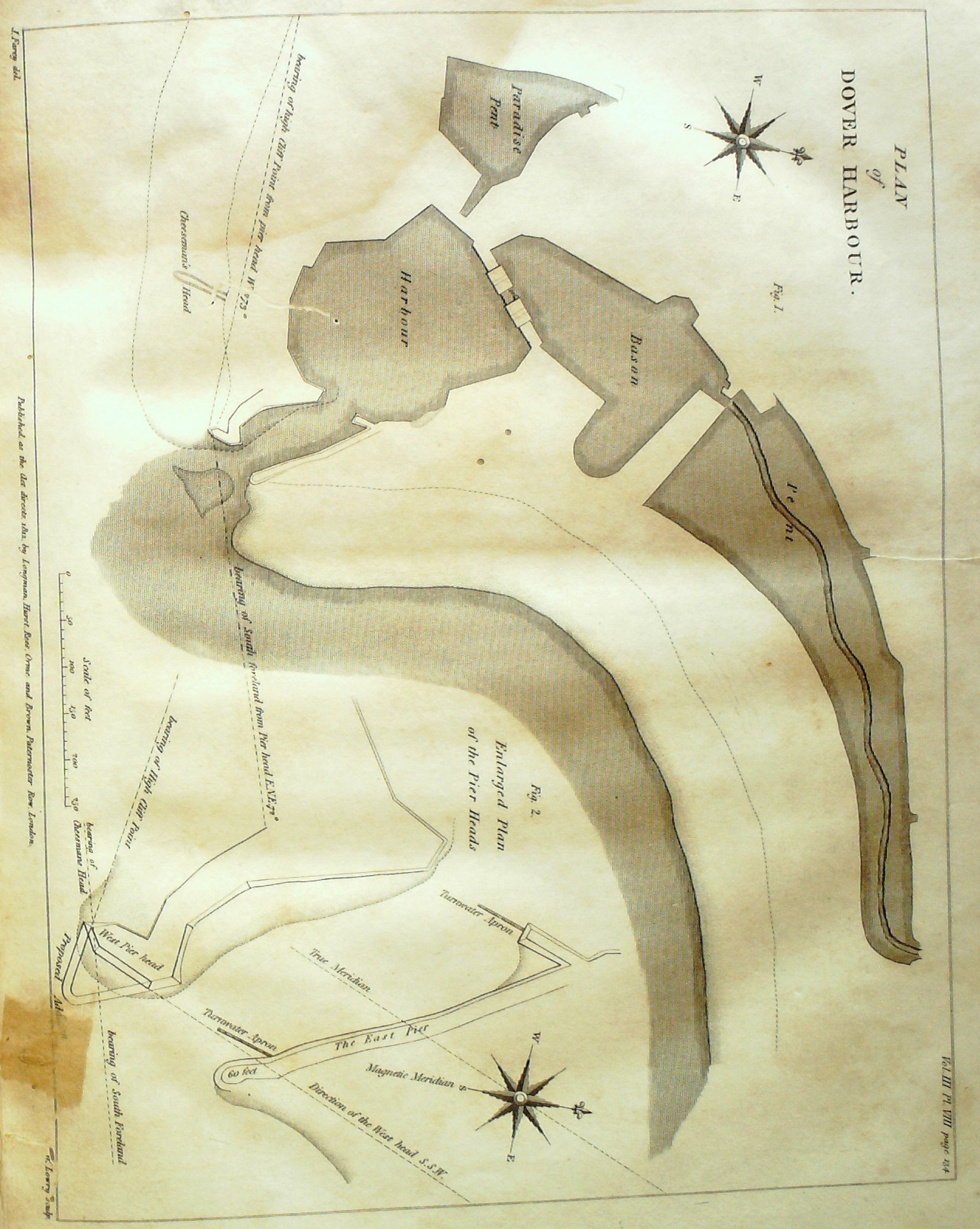
(See Plan, Plate 8.)

The REPORT of JOHN SMEATON, Engineer, upon the Harbour of Dover.

THIS harbour appears from old accounts to have been a national object for ages paſt, as being the neareſt port, and conſequently from its ſituation the key between England and France; on this account great ſums of money have been from time to time expended in keeping it open and rendering it as commodious as the nature of its ſituation will admit; yet notwithſtanding every endeavour for this purpoſe it ſtill labours under ſome natural inconveniencies, which it is greatly to be wiſhed were removed. For this purpoſe, at the deſire of the Right Honourable the Earl of Holderneſſe Lord Warden of the Cinque Ports, I went down to view and examine the harbour of Dover in February laſt, where I had every aſſiſtance the place would afford.

The port of Dover has in length of time gone through many changes; the mouth or entry thereof being at preſent in a very different place from what it was within the compaſs of record, as appears by accounts thereof collected by Mr. Hammond of Dover, with the peruſal of which he was ſo obliging as to favor me. This great change has been evidently brought about by the ſame cauſe that has at all times been, and ſtill continues to be its greateſt annoyance; viz. the conſtant motion of the beach or ſhingle which by the action of the ſeas is driven coaſt ways from weſt to eaſt; for as the Britiſh channel opens to the weſt and contracts to the eaſtward, the ſeas are much more violent and heavy from the ſouth-weſtern than from the ſouth-eaſtern quarter; and in conſequence, though it may be apprehended that on violent ſtorms at S. E. the ſhingle may in ſome degree be moved weſtward, yet the general prevalence being the contrary way, the moſt apparent and obſervable motion is coaſtways from weſt to eaſt.

This ſhingle or beach (as it is called) conſiſts chiefly of flints that ſeem to have originally proceeded from the chalk cliffs that inveſt a conſiderable part of the ſouth coaſt of England; which cliffs being gradually undermined by the action of the ſeas at the foot thereof, tumble down, and often in very large quantities; where by degrees the chalk diſſolves by the action of the ſun, the ſea, and the froſts, and the flints being broken and inceſſantly



rubbed againſt each other, form a conſtant ſucceſſion of beach. This however is obſervable, whether this ſucceſſion is to be attributed to the above or any other cauſe, that an immenſe quantity of beach is in a ſtate of continual motion along the coaſt from weſt to eaſt, part of which lodges and fills up every receſs where it can be depoſited and lie in quiet.

This beach has formerly been the deſtruction of the old harbour, and it appears from the above accounts that the mouth has been more than once entirely ſhut up, and has remained ſo for years; and that the mouth of the preſent harbour was originally a cut through the beach to let off the land waters pent up in the inſide of the harbour, in order more effectually to view and examine the ſtate thereof, and to enable the engineers to conſtruct ſuch freſh works as might appear neceſſary for its re-eſtabliſhment.

From this ſtate the preſent harbour has been gradually improved; the entry whereof is defended by two piers compoſed chiefly of wooden piles, the inſide filled with rough heavy ſtones. After paſſing the throat or entry, the veſſels arrive in a capacious outward harbour, where they may lie defended from all winds; but having an open communication with the ſea the water flows and ebbs therewith, and at low water ſpring tides the whole is left dry. Above this the natural capacity of the harbour (as it ſeems) is divided by a dam, or as it is called the *croſs wall*, in which is an opening of 38 feet wide at top, and about 36 at bottom; and in this is placed a large pair of gates pointing to landward, through which veſſels at high water may paſs out of the exterior harbour into the interior harbour or baſon (as it is called) where occaſionally they are kept afloat.

This croſs wall beſides the great gates, has two other openings of about twelve feet wide, in each of which is placed a pair of draw gates.

The interior harbour or baſon is again divided by a ſecond dam or croſs wall having an opening of more than 20 feet for the paſſage of ſmaller veſſels, which is alſo furniſhed with a pair of gates pointing to landward; this dam has likewiſe another opening furniſhed with three draw gates, by which the water can be occaſionally let off ſo as to ſcour the baſon. Into this upper reſervoir, which is called the *Pent*, the freſh water river which ſprings from the chalk hills north of Dover empties itſelf, and makes its way through both ſets of gates, through all the three harbours, and laſtly betwixt the pier heads to the ſea.

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This general diſpoſition of the harbour appears to me as judicious as can be contrived, and is upon the ſame general idea as the port of *Cherbourg* upon which the French had expended an immenſe ſum of money, in order to compleat every thing in the moſt ſubſtantial manner, before it was deſtroyed by the Engliſh in the laſt war.

According to this diſpoſition, when by hard gales of wind and ſeas from the ſouth-weſtern quarter, a quantity of beach is brought round the weſtern head and lodges itſelf between the heads; the baſon and pent are then filled partly by taking in the ſea water and partly by freſh-water afforded by the river, and there retained till it be low water. The draw gates of the ſluices in the croſs wall are then opened with all poſſible expedition, and the body of water contained in the baſon and pent, by making its way between the pier heads cuts down and removes the bar of the beach, which at the time of ſpring tides is done with ſo great effect, that at one ſingle operation, as I am informed, a good paſſage is opened for veſſels; and at two tides the whole mouth of the harbour can be cleared; and could this be done with equal eaſe and expedition at all times when wanted, then would the evils that are now complained of not ſubſiſt, and this port would be in nearly the beſt condition its ſituation is capable of; and which indeed is very reſpectable as a tide harbour, having a good capacity, with from 16 to 18 feet water at common ſpring and from 11 to 13 feet water at common neap tides: but it ſo happens when there are ſtorms or hard gales of wind from the ſouth-weſtern quarter and at the ſame time ſhort or low neap tides, that ſuch a quantity of beach will be lodged between the pier heads, and to ſo great a height, that according to my information a veſſel drawing but four feet water can hardly get into or out of the port, at a time when if the mouth were clear as uſual, there would be good ten or eleven feet water into and out of the outward harbour.

At thoſe times there remains at low water ſo great a depth without the heads, that the water from the ſluices has not a ſufficient fall and power to drive out the beach from between the heads, but it is obliged to lie till the ſpring tides come on; which as it may ſometimes happen to be an interval of a week, produces great obſtruction to the paquets eſtabliſhed between Dover and Calais, as well as to the mercantile trade of the place; and yet more to general trade, as veſſels may want the port for ſafety during theſe intervals but cannot enter it.

The remedy for this evil, or as far as it is capable of remedy, is as I apprehend the object of the preſent enquiry; and towards this end two general methods preſent themſelves; viz.

1ſt. The

1ſt, The prevention of the beach from getting into the harbour's mouth, and

2dly. A more effectual way of clearing it out when it happens to get in at the times above ſpecified.

It has long been obſerved that when, by the waſhing of the ſea at the foot of the chalk cliffs, any conſiderable fall of the cliffs happens to the weſtward of the port, this ground ſo fallen making a projecting point or promontory further out than uſual ſtops the courſe of the beach coaſtwiſe, ſo that when the quantity which happens to be laid eaſtward of the falls (as they are called) has got beyond the port, the quantity paſſing the pier heads is ſo ſmall that the port is very little annoyed therewith; but as thoſe falls are chiefly compoſed of chalk, and much broken by the ſhock in falling, the ſea in the courſe of a few years waſhes them away, and then not only the beach is let to paſs in its ordinary quantity, but alſo the quantity before retained by the falls, which gradually eſcapes as the fall (or artificial point) waſhes away. This has given occaſion to a ſuppoſition, that if inſtead of theſe temporary promontories (which are often ſo conſiderable as to cover ſome acres of ground), fixed heads or jettees were run out into the ſea, which were not capable of being waſhed away, they would for ever prevent the beach from getting eaſtward into the harbour; for, ſay they, ſo long as theſe falls or natural jettees laſt, ſo long is the harbour free from beach; eſpecially in ſuch quantity as to prevent its being eaſily kept clear by running the ſluices, and therefore is no annoyance thereto. This matter, as it depends upon facts that are in themſelves at firſt ſight ſtriking, and on that account ſtrongly inſiſted upon by many, I ſhall endeavour to ſet in a clear light.

When I was at Dover in the month of February laſt, a very large fall, about three miles to the weſtward of that port, had happened but a little while before; as well as another large one nearer to Dover, which had happened ſome time previouſly; both theſe falls I went to view and conſidered very attentively. I judged that the great fall (as had been repreſented) covered ſix or eight acres of ground, and will undoubtedly take a conſiderable time to waſh it away. I obſerved that the quantity of beach lining the ſhore gradually diminiſhed, as we approached both theſe falls from the eaſtward, ſo that near thereto the ſhore was in a manner clear of beach on the eaſt ſide, while there appeared to be a quantity gathering on the weſt ſides, and which was in a ſtate of increaſe, as muſt neceſſarily happen by the gradual approach of the beach from the weſtward.

Undoubtedly till theſe promontories get charged to the full with beach, the greateſt part will be there retained, and in conſequence the conſtant ſupply being cut off, the quantity eaſtward

eaſtward of the falls will gradually diminiſh by removing ſtill further eaſt. That theſe falls if rendered permanent would permanently retain a quantity of beach ſufficient to charge them, and in conſequence make an addition to the coaſt for ſome ſpace weſtward thereof, I can readily admit; but that after they are full charged with beach they will continue to ſtop the conſtant ſupply from getting round theſe heads, and again driving along the coaſt eaſtward as it had done before, is what is by no means clear to me. The matter rather preſents itſelf to me in this light; that in fact by ſuch time as theſe falls get fully charged with beach, or perhaps ſooner, they get ſo far waſhed away as to begin to looſe it again; and as by this means their power of retention, *after they are full*, never comes to the proof, this makes it to be imagined that the beach begins to move eaſtward merely in conſequence of the falls waſhing away; and therefore had the point been permanent, the beach would always have been ſtopped.

That the time taken up in the waſhing away of theſe falls may in ſome meaſure correſpond with the time they take to fill, appears hence, that the largeſt falls are the longeſt in waſhing away; but then they will confine and lodge more beach before they are full. I can therefore readily admit that if jettees were run out to the ſame length as thoſe falls, they would if properly maintained permanently retain a *certain quantity* without afterwards letting that quantity go again, as the temporary falls or jettees now do; but as I am no ways convinced that they would tend to ſtop the conſtant ſucceſſion of beach from getting round their heads after they are full, and then driving along the coaſt as before; I am of opinion that the good that is to be got to Dover harbour by raiſing artificial jettees in order to lock up a certain quantity of beach as in a cheſt, will be no ways adequate to the expenſe of raiſing them, but that the ſucceſſive quantity will in fact fill them as faſt as they can be carried out by men's hands; ſo that a remedy this way muſt conſiſt in an eternal work of building jettees, which as they will require maintaining as well as building, will, together with the common repairs of the harbour works, induce a very great expenſe.

It is ſaid indeed, that though the heads may not retain the beach beyond a certain quantity, yet that if it be forced to go out into deep water, it will be loſt in the ſea and never return upon the coaſt. But in anſwer to this, I fear it will not be poſſible by the hands of man to carry out thoſe jettees into ſuch deep water upon this ſloping coaſt, as to prevent their return; nor indeed, when I obſerve how oddly this beach gets along the coaſt through paſſes where it muſt go through deep water, and afterwards appears again, I am not inclined to truſt altogether to the ſhoving it out into deep water, even if it could be done. I am therefore more ſtrongly induced (without neglecting any advantages that may

may be drawn from thoſe caſual and temporary reliefs of nature, the falls) to confine my views, operations, and expenſe to ſuch purpoſes as have a determinate end, and which ſuppoſe the beſt to be made of it that can be, under the ſuppoſition of a conſtant ſucceſſion of beach from weſt to eaſtward upon the coaſt as heretofore.

Conformably to this doctrine of the movement of the beach, may be reckoned the real benefit found by the jettee that has been erected at the Caſtle Point. It ſeems that formerly the breadth of ground between the pent and the ſea was ſo narrow, that there was great danger of the ſeas making a thorough breach into it; but that upon a large fall happening at the Caſtle Point, a quantity of beach was lodged and the partition between the pent and the ſea was greatly ſtrengthened as long as the fall laſted; but upon the waſhing away of this fall the barrier was again greatly weakened; which being obſerved, an artificial pier or jettee was erected at the ſame place, and ever ſince the beach has been ſo far retained as to lie in a conſiderable breadth and ſtrength between the pent and the ſea, and ſo as to put that matter out of all danger. This was certainly a very judicious piece of work, and the effect was fully accompliſhed, that is, of retaining a quantity of beach to the weſtward of it, ſo as to make an *addition to the coaſt*; but this being once made to as great a degree as the projection of this head is capable of retaining it, the further quantity coming from the weſt and paſſing by the mouth of Dover harbour, is not retained by this head but gets round it, is again gradually waſhed up upon the ſhore, and purſues its former courſe, and probably gets round all the heads and forms the beach in the Downs.

To the weſtward of the harbour's mouth is erected a pier, jettee, or breakwater, called Cheeſe-Man's Head, whoſe effect has likewiſe been to lock up a quantity of beach, and thereby to make an addition to the coaſt. While this was doing, the good effect thereof to the harbour was experienced, but being now in a ſtate of decay, the beach it formerly retained is coming down; however as the natural ſupply will undoubtedly be cut off for ſome time by the falls to the weſt, it ſeems to me, on mature conſideration, to be more adviſeable to take the benefit of this intermiſſion, and to employ the preſent powers in raiſing a work that will more permanently and directly tend to the relief of the harbour than the repairing of Cheeſe-Man's Head.

The natural direction of the entry of the harbour is S. E. by the preſent magnetic meridian, or about E. S. E. by the true meridian; but to avoid confuſion I ſhall confine myſelf in the mention of the points of the compaſs to the magnetic bearings only. The ſhape of the weſtern head is not only very uncommon but to me very extraordinary; for after

after it has been carried out in the natural direction of the harbour's entry, for about 30 feet, in a line at or about S. S. E. it ſuddenly turns away to S. S. W. in which direction being carried on between 60 and 70 feet, it is terminated with a ſalient angle pointing to the ſame quarter. The line of direction of this flank of the pier being continued in an oppoſite direction, cuts within the eaſtern pier head about 60 feet, ſo that with all winds betwixt S. S. W. and E. S. E. this flank is ſtruck obliquely by the ſeas, and acts in the manner of a tunnel, towards bringing the ſeas (with wind from S. to S. S. W.) and conſequently the beach that happens to be lodged before the mouth of the harbour, directly into the throat thereof. The ſouth-eaſtern ſeas indeed are ſo ſhort that they do not much affect the mouth of this harbour any way; but by the pier turning ſo much to the weſt it greatly facilitates the beach after it has got round its ſalient point to get along this flank, whoſe line of direction being overlapped as already pointed out by the eaſtern head, is thereby equally caught and retained, when the wind is more to the weſt than the S. S. W. direction of this flank; for it is very obſervable that the ſeas will wrap themſelves round a head, and act with great power ſeveral points of the compaſs from the wind that cauſes them. Nothing therefore, as it ſeems to me, could have been formed more improperly with reſpect to the bringing of beach into the throat of the harbour, nor indeed, in all ſoutherly winds, with reſpect to bringing in the ſeas into the harbour, had not this laſt effect been in ſome meaſure prevented by the jettee or tongue projected from the eaſtern pier at the inner entry into the harbour which catches them as they run along-ſide of the eaſtern pier.

I would therefore adviſe, by way of leſſening as much as poſſible the quantity of beach that can get round and lodge between the pier heads, and as the firſt and moſt important work that can be done, to prolong or carry out the firſt mentioned line of the head in its direction S. S. E. and that far enough to come into a S. S. W. direction from the extremity of the eaſt head, which will be done by extending this face about 90 feet, as ſhewn in the plan hereto annexed, and then returning the outſide ſo as to fall in with the ſalient points of the preſent pier. The additional work will form a ſort of triangle, whoſe baſe will be principally formed by the preſent S. W. flank, and whoſe projection forward towards the S. E. in a line perpendicular to the baſe, will be but little above 60 feet further out than at preſent. By this conſtruction all the good that ariſes from the ſhape of the preſent pier head, in regard to locking in the beach, will be retained; and as all winds that are farther out than S. S. W. (that is than ſouth of the true meridian,) which include all thoſe which are the moſt prejudicial, will meet the outface of the new work obliquely, they will rather tend to ſend the ſeas and beach to ſeaward, than to bring them round the head into the throat of the harbour; and as to all thoſe winds that are eaſtward of the S. S. W. they are

are found to be productive of no ill effect upon this harbour. The intent then of this projection is not by way of lengthening the head, ſo as to make it lock in or retain a greater quantity of beach, but by making it to overlap the eaſtern head ſufficiently, to cauſe the beach brought coaſtwiſe by the great ſeas at W. S. W. to ſhoot beyond the eaſtern head, before it is brought up again upon the ſhore, and by giving it ſuch a ſhape as ſhall alſo tend in the moſt effectual manner poſſible to make the beach drive out to ſea till it has paſſed the harbour's mouth.

I am ſenſible at the ſame time, that neither this nor any other ſhape or prolongation of the piers will totally prevent the beach from coming into the harbour's mouth; for though this reaſoning would hold good in caſe the waves of the ſea were reflected from fixed objects, like light from poliſhed ſurfaces; yet the ſeas, as already obſerved, ſo wrap round the ſurfaces of bodies that oppoſe them, that they will in ſome degree go round even while they come into an oppoſite direction. They may therefore more aptly be compared to the nature of ſound than light; yet as the groſs and violence of the action is ſpent according to the angles and directions wherewith they firſt ſtrike, the main force or ſtreſs of the action will conform to thoſe laws; and hence (as it may be expected) if two thirds of the whole quantity of the beach that now would lodge itſelf in the harbour's mouth is diverted ſo as to paſs by it without entering, it will follow that the third part will not be of one ſixth of the evil conſequence and inconvenience to the harbour; and that rendered more eaſily and readily to be removed by the action of the ſluices.

It is perhaps impoſſible to make a compleat artificial harbour, for what improves it in one ſenſe will often be of detriment in another; for this reaſon the main drift and purpoſe thereof is to be principally attended to, and when that is done to as great an advantage as may be, that harbour may be ſaid to be in the moſt perfect ſtate its ſituation is capable of. I am therefore aware that this addition to the head here propoſed may meet with ſome objection from ſeamen; for it may be argued that the preſent weſterly turn of the head admits ſhips coming from the weſtward with a ſcant wind at N. N. W. more eaſily and readily to ſhoot up into the wind and get between the heads, (from whence they warp into the harbour) with leſs riſque of over ſhooting their port, than if this prolongation were to take place. To this I anſwer, that as there is frequently a bank of beach lodged high againſt the pier in the very place where the new work is propoſed (ready to be driven in between the heads by the firſt ſhift of wind more ſoutherly), this will either by the reality or the fear thereof prevent veſſels from making the turn of the weſt head ſooner, eſpecially if they have no pilot on board, than if this vacancy were occupied with a ſolid pier, which they will always have the advantage of ſeeing above water, and againſt which, from its ſhape

ſhape and poſition, no material quantity of beach can ever lodge. I muſt alſo obſerve that if a ſhip is coming up the channel intending for this port, ſhe always has either the wind at large, ſo that ſhe can keep a proper offing and alter her courſe proper to run right into port, or elſe it is an off ſhore wind, wherein if ſhe pleaſes ſhe may drop an anchor before the harbour's mouth and afterwards warp in.

2dly. It may alſo be alleged that the preſent face of the pier head is ſometimes uſeful for ſhips to lie along ſide; in order to caſt off when the wind is fair to go up or down channel, and with ſuch a wind as does not enable her to *ſail* out of port: but it may be obſerved in anſwer that beſides the objection, that when a bank of beach is lodged here no uſe can be made of this ſide of the pier for this purpoſe; it may be further obſerved that for all ſhips going eaſterly, the propoſed eaſt face will be better adapted in ſoutherly winds than the preſent; and for ſhips going weſterly, a tranſport buoy fixed at a proper diſtance to ſouth-eaſtward of the harbour's mouth, would anſwer far better for this purpoſe than the preſent pier, and that, even independently of ſuch a buoy, there are ſome winds which the propoſed face would anſwer to better for ſhips to caſt off from to proceed weſterly than the preſent. I am told that ſuch a buoy has been formerly fixed and maintained, and it ſeems very adviſeable that it ſhould be replaced *.

This in my opinion is the whole and moſt effectual means that can be uſed to prevent as much as poſſible the beach from getting into the harbour's mouth. I come now to conſider the moſt effectual method of removing what does come in.

In the time of ſpring tides, as has been already obſerved, there is no difficulty; and in regard to neap tides, as the quantity that can get in will after the execution of the propoſed head be far leſs than at preſent, it may with more eaſe be removed, even with the preſent power; but as that does not ſeem ſufficient to be abſolutely depended upon, I ſhall now ſhew what is in my opinion the moſt effectual way to improve it.

On Thurſday morning the 23d of February, being the third day after the full moon, a full head of water was penned in and the turn-water next the eaſt pier head ſet, I obſerved the ſtate of the beach about and between the heads, (which indeed were tolerably clear) before the ſluices were played at low water, in order that I might ſee the operation thereof. I obſerved that the gates of the ſluices were five minutes in drawing, and that the water

* The prolongation of the weſt head and fixing a tranſport buoy, I find was adopted by Captain Perry in his report on this harbour 1718.

took

took up the ſame time in getting down from the ſluices to the pier heads, that it was five minutes more in getting to its full ſtrength, which continued for about half an hour; but after that, though it continued a quarter of an hour longer, the effect was inconſiderable. After the operation I obſerved that wherever the beach had laid in the way of the water, it was greatly reduced and carried ſo far without the heads that the weſterly ſeas would infallibly carry it beyond the eaſt head, and prevent its returning into the harbour.

I obſerved that before the ſluices were drawn there did not appear to be above ſix or eight inches of fall from the apron of the outmoſt turnwater to the ſea, and about an equal declivity from the ſtone apron of the great gates to the ſaid turnwater apron, ſo that from the ſtone apron of the great gates to ſea, the fall could not much exceed a foot, or at moſt eighteen inches of declivity, but this will be variable according as the tide ebbs more out; I only beg leave to obſerve that this will be the ordinary ſtate of it in ſpring tides, as the preſent ones were ſaid to be of a middling kind. I obſerved further that the water from the ſluices when in their full power ſcarcely overtopped the turnwaters, which appeared to be about three feet and a half high, ſo that the fall of the water's ſurface from the turnwater to the ſea was ſcarcely more than four feet; and yet in this ſtate the ſluices are capable of keeping the harbour clear. I was informed that at neap tides ſometimes the water will ebb down to the ſtone apron of the great gates, but ordinarily ſo as to leave about twenty inches upon it, ſcarcely ever more than two feet, if it be not penned by beach caſt into the harbour's mouth. Hence it appears that at neap tides there is not above three feet more depth of water at the harbour's mouth than at ſpring tides, and conſequently by a power of water that will overtop the ſea water at neap tides as much as it now does at ſpring tides, the harbour's mouth might be cleared as effectually at neap as it is now at ſpring tides, and this would be effected if the capacities of the ſluices were doubled; for the ſame deſcent of the ſurface would produce the ſame velocity and effect upon the bottom, and being confined to the ſame breadth a double quantity of water would produce a double height, which would then have as good or a better fall into the ſea at neap tides, than it now has at ſpring tides.

It is true that being diſcharged in double quantity it would be ſpent in half the time, ſo that inſtead of laſting half an hour in full vigour, it would laſt only a quarter; but as a much greater body and weight of water will act at once a conſiderable effect muſt be produced, ſo as greatly to relieve the harbour's mouth, which though not made perfectly clear till the approach of ſpring tides, would, in conjunction with the relief that is to be expected from the propoſed addition to the weſt head, prevent its ever being barred up at neap tides or prevent its uſe to all middling veſſels; for even a ſingle diſcharge of the

ſluices

ſluices with the power I have mentioned, would in a manner remove the groſs of any obſtruction that then could happen.

I was informed that in ſummer they can generally gather a full baſon and pent of water in four days, and one in a week in the very drieſt ſeaſons and ſhorteſt tides; if ſo the pent might always be kept full againſt neap tides, ſo as to fill the baſon or nearly ſo on ſhutting in the firſt tide that ſhall happen after the approach of any emergence; I ſay the approach of any emergence, for whenever it comes to blow at ſuch points as are found by experience to bring in the beach, it is not neceſſary to wait the event but to prepare immediately to get a full head of water.

There are two ways by which the capacity of the ſluices may be augmented. One is by building a new tunnel at each end of the preſent ſtone wall. The width of the preſent tunnels or archways for the draw gates is twelve feet, but as I am perfectly clear that the advantage of the ſluices does not ſo much depend upon the length of time they play, as upon the great body that can be at once diſcharged; I would adviſe that the new tunnels would be fifteen feet wide each, and not be ſhut by draw gates but by turning gates, by which the water can be inſtantly diſcharged without loſs of time or addition of hands. The execution of this method will require the moſt time and expenſe, but when done will be the moſt durable and require the leaſt repairs.

The ſecond method is by placing turning gates in the great gates, which can be diſcharged and will operate like the former, and anſwer the end in all reſpects the ſame: the only objection to this method, is, that folding gates made with turning gates encaſed are not only more expenſive to conſtruct, but leſs durable than folding gates made plain and whole; otherwiſe the buſineſs will be done in this way at far leſs expenſe and in much leſs time than with ſtone tunnels, eſpecially as the great gates having been lately renewed may be made ſtill to ſerve by having turning gates adapted to them.

As I do not know of any turning gates encaſed in folding gates in England, it perhaps may be doubted whether the thing be practicable, but for their information I beg leave to mention that this very thing is done and practiſed with ſucceſs, not only at the Briel but in the great gates of the ſluice of Helveot in Holland, and made uſe of for ſcouring the outward harbour and pier heads, and that it was formerly done in the great ſluice of Mardick near Dunkirk, before it was demoliſhed by treaty.

As therefore this method can be put in practice in a ſhorter time, and at a leſs expenſe, I would the rather adviſe it at preſent to be adopted, that when the good effects thereof are ſeen, the larger and more durable work in ſtone may be doing while the firſt pair of gates are in wear, which may afterwards be changed for thoſe of the preſent conſtruction when the others are executed.

The ſluice of Helveot is forty-eight feet wide: the gates, which I ſaw the year 1755, by a date upon them, appeared to have been conſtructed in the year 1722, ſo that they had been in thirty-three years, and were then in perfect good repair; they had however originally been exceedingly well conſtructed and very ſtrong. I happened to have an opportunity of ſeeing the operation of this ſluice, which I well remember was far beyond the preſent ones at Dover, though the turning gates encaſed in the great gates were the only apertures they had for diſcharging the water from the baſon, which, according to my idea, is much leſs than the Dover baſon and pent together; the whole operation was in a manner over in a quarter of an hour.

The addition to the weſt head I would adviſe to be of ſtone, which will not only be more durable and in the end cheaper than wood, but will probably ſhew the way of rebuilding the preſent piers with ſtone as they may occaſionally want it, which it is to be wiſhed had been done at firſt.

The outſide of the new work I would propoſe to be conſtructed of Portland blocks, but the inſide may be done with the large rough ſtones that are brought from Folkſtone, ſuch as are uſed for filling the preſent piers. I would however adviſe, that to the height of ſix or eight feet, the ſouth face of the propoſed addition may be done with Corniſh moor ſtone, as the expenſe will not create any material difference upon the whole, and its hardneſs will prevent its being affected by the beach rubbing againſt it.

It would be beſide the preſent purpoſe to make out deſigns for the execution of the propoſed works, till the execution ſhall be reſolved upon; and yet without this it is not poſſible to come to any complete eſtimate: however by way of giving ſome general idea of the expenſe, I ſuppoſe the ſtone head may be done for the ſum of £7,500. and the gates made upon the plan I have mentioned, for the ſum of £1,500, including an addition to the apron to prevent the action of the water from gulling the bottom.

Either the increaſing the water way or the addition to the pier, I expect will be of great ſervice to the port, and as one is chiefly maſonry and the other carpentry, if proper funds can

can be raiſed they may be both carried on together; but if they are to be carried on ſeparately, I look upon the alteration of the head as of the moſt immediate conſequence and importance.

It may be proper to ſuggeſt that when the port of Dover is by the means above ſpecified put upon the beſt footing its ſituation is capable of (that is, according to the beſt of my judgement) I apprehend it will be very eligible to be more frequently uſed by the king's ſloops and leſſer frigates, and therefore that for fitting them out it would be very practicable to build a dock in the place now called the Paradiſe Pent, which is in a manner a waſte piece of ground, and where the excavation for the purpoſe is in a great meaſure ready; this having been in ancient times, as I underſtand, a very material part of the harbour.

Auſthorpe,
17th *June* 1769.

J. SMEATON.

OPERATION of the Turning Gate Sluices for Dover Harbour.

When the gate is to be ſhut for penning in a head of water, the rope from the crab is to be hooked to the downſtream ſide of the gate, and by that means brought cloſe to its bearings. When the water comes againſt it the other half of the gate will be ſupported by its threſhold and cheek, in the ſame manner that common ſluice gates generally are, but as the part of the gate that lies downſtream when open, receives no ſupport from either, in order to give it that ſupport, a triangular frame called a Valet, turning upon two gudgeons is brought round, and acting as a lever, its turning poſt is made to bear hard againſt the clapping poſt of the gate, and thereby firmly ſupports it, and preſſes it upward againſt its cheek, which it would otherwiſe be inclined to depart from; and in order to make it the more tight, an eye upon the end of the diagonal lever of the valet is brought towards an eye upon the fixed beam by a luff tackle, and in that ſituation is laſhed by ſeveral turns of a cord round the pummels; this done, the crab rope is to be hooked, and then the gate is ſet for penning in a head of water.

In

In order to diſcharge it, the laſhing is to be cut, and a part of the gate being then unſupported, will throw open the valet, and in part open itſelf, but to ſet it right ſquare the crab is to be made uſe of, and will be ſtopped in its proper poſition by the counter threſholds. The water then runs through in a full bore, and by its ſuperior accumulation in the exterior harbours, will act in proportion more ſtrongly upon the beach at the entry of the pier heads.

N. B. By giving the greater ſide of the gate ſtill more advantage, it might be made to open wholly of itſelf, but as its operation would then proceed with violence, it is judged more ſafe to have recourſe to two or three turns of the crab, at which a ſmall power will ſerve, the gate being nearly in equilibrio.

REMARKS.

According to my notes, the overfalls of the draw gates are about eighteen feet above the floor of the great gates. The floors of the turning gates are propoſed to be one foot higher than that of the great gates, and being fifteen feet above the floor, they will pen in ſixteen feet head of water, which will be fully ſufficient for the neap tides, at which time theſe gates are principally ſuppoſed to be of uſe. When the full head of eighteen feet is to be penned; the water is to be ſtopped from going over betwixt the top of the turning and the croſs beam, by flaſh boards, and as on all occaſions the draw gates are to be firſt opened, by ſuch time as that is done the head of water will be run off to the level of the turning gates which may then be diſcharged alſo: this being judged more ſafe than to raiſe the turning gates to the full height of eighteen feet.

Auſthorpe,
18th *June* 1771.

J. SMEATON.

ESTIMATE

ESTIMATE for erecting one of the Turning Gate Sluices, proposed at Dover Harbour, of fifteen feet water way, by John Smeaton, Engineer.

	£	s.	d.
To erecting a dam of rabbetted piles so as to pen the water in the bason to its proper height, and defend the foundation of the sluice from the rise of the tides, the timber work being supposed to be completed in place at 5s. per foot -	400	0	0
To a similar dam towards the outward harbour to pen out the neap tides from the foundation - - - -	400	0	0
To a horse engine for draining the water, complete - -	150	0	0
To piling machines and other utensils - - -	200	0	0
Preparation -	£ 1,150	0	0

N. B. The materials of the dams together with the engines and utensils will be equally serviceable in the second erection as the first, and at last sell as old stores.

The FLOOR.

	£	s.	d.
To 1008 feet of fir timber in bearing piles, supposed ten inches square, and eight feet long, preparing, shoeing, and driving included, at 4s. per cube foot -	201	12	0
To the main sell of fir timber, framing, jogling, bolting, and laying down, containing 175 feet, at 5s. - - -	43	15	0
To 648 feet of fir timber in the common sells, preparing, levelling the pile heads, and trenailing down, at 3s. - - - -	97	4	0
To 180 trenails of $1\frac{1}{2}$ in., at 6d. - - -	4	10	0
To 972 feet superficial of four inch plank piling of beach, elm, or fir, at 3s. -	145	16	0
To 150 cube yards of chalk rubble, to be rammed under and between the sell timbers, at 3s. - - . - -	22	10	0
To planking the floor, containing 1060 feet superficial of three inch fir plank to be lathed and put together with tar and hair, at 1s. 6d. - -	79	10	0
To forty-two feet of oak timber in threshold framing, laying down and bolting, at 6s. - - - - - -	12	12	0

IRON WORK.

	£	s.	d.
To 8 cwt. of iron work in bolts, plates, &c. for the main sell and thresholds, at 6d. per lb. - - - - -	22	8	0
To 12 cwt. of spikes for the pile planking and floor, at 36s. - -	21	12	0
Total of the floor -	£ 651	9	0

The

The SUPERSTRUCTURE.

MASONRY.

	£	s.	d.
To 10,638 cube feet of Portland stone to be set in pozzelana * or terras mortar, at 3s. per cube foot, all work included - - -	1,595	14	0
To 9,751 cube feet of rubble backing, the mortar to have a mixture of pozzelana equal to one-third of its proper quantity of sand, at 1s. - -	487	15	0
To an allowance of 3d. per foot, upon the top area for dressing stones, for paving, letting in cramps, &c. containing 1,908 feet - - -	23	17	0

IRON WORK, &c.

	£	s.	d.
To iron work in cramps 3 cwt., at 4d. per lb. - -	5	12	0
To lead for fixing them, 3 cwt. at 2d. per lb. - - -	2	16	0
To oil, &c. - - - - -	0	10	0
Total of the superstructure -	£ 2,116	4	0

The GATE, VALET, and CROSS BEAM.

CARPENTRY.

	£	s.	d.
To 138 feet of oak timber in the turning post and cross beam measured in square in place at 6s. - - - -	41	8	0
To 248 feet of oak timber in the ribs, clapping posts and valet measured in square, at 5s. - - - - -	62	0	0
To 220 feet of two inch fir plank for planking the gates on both sides, at 6d.	5	10	0
To framing and fixing the above, and letting in the iron work, containing 423 feet solid, at 2s. 6d. - - - -	52	17	6

IRON WORK.

	£	s.	d.
To one ton of cast iron in gudgeons, pots, and boxes, at 22s. per cwt. -	22	0	0
To 28 cwt. of forged iron work, in plates, bolts, &c. at 6d. per lb. -	78	8	0
To 2 cwt. of spikes for the planking, at 36s. - - -	3	12	0
Total of the gate, valet, and cross beam -	£ 265	15	6

* N. B. Pozzelana has been imported from Italy to different parts of Great Britain, at the price of 40s. per ton, containing about twenty-four bushels each, and preferable to the same quantity of terras.

The

	£	s.	d.
The crab with ropes, blocks, and iron work complete - -	50	0	0
To drainage of the fluice while building, fuppofing the labour of four horfes for fix months, or 180 days, at 3s. per day each, with two drivers at 2s. per day each, in the whole 16s. per day - - - -	144	0	0
To 600 tons of Folkeftone rubble ftones of promifcuous fizes, for fecuring the apron of the fluice, at 6s. 6d. - - - -	195	0	0

ABSTRACT.

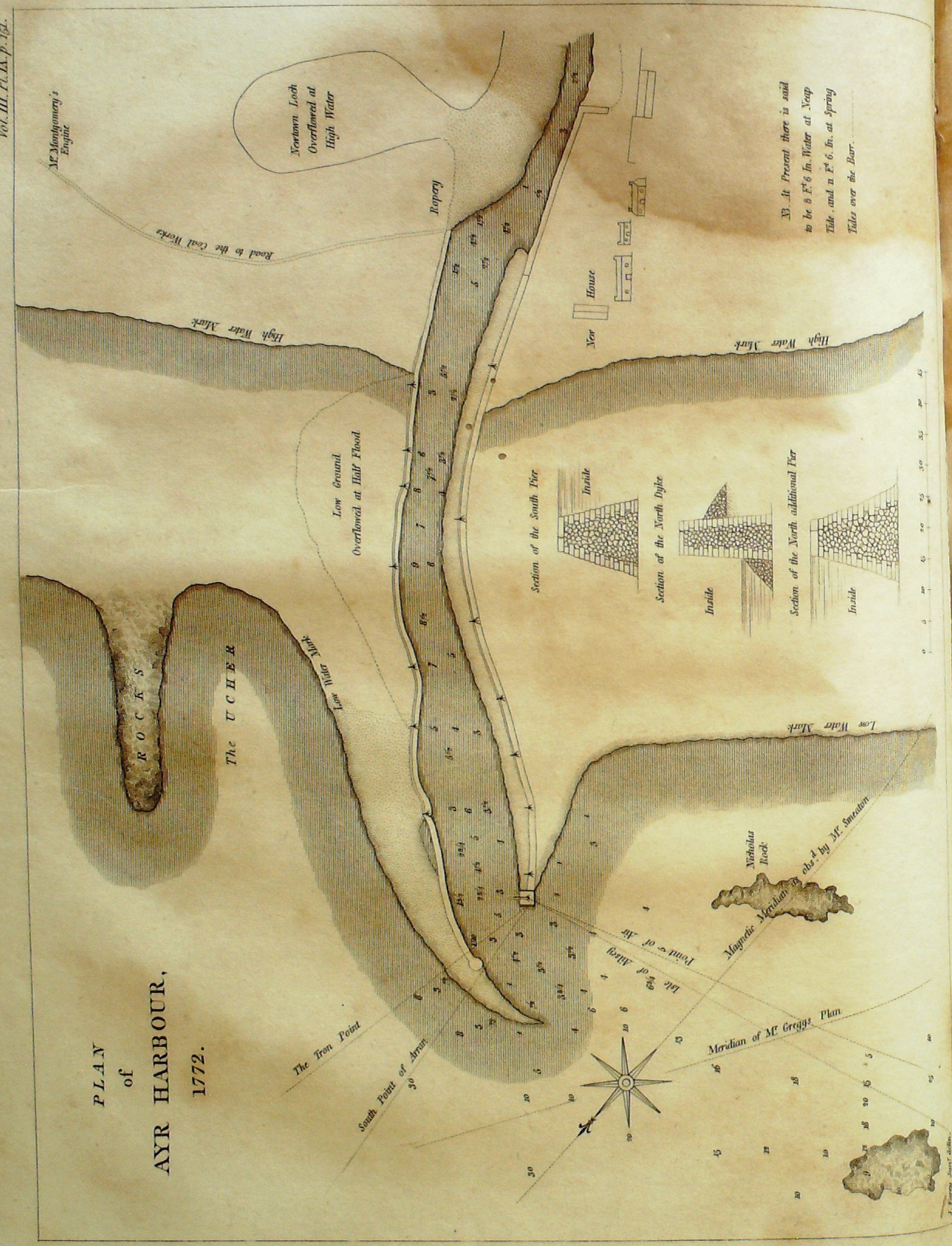
	£	s.	d.
The preparation - - - - -	1,150	0	0
The floor - - - - -	651	9	0
The fuperftructure - - -	2,116	4	0
The gate, valet, and crofs beam - - - -	265	15	6
The crab, ropes, &c. - - - -	50	0	0
Drainage of the fluice - - - -	144	0	0
Folkftone rubble for fecuring the apron - - -	195	0	0
Neat eftimate -	£ 4,572	8	6
Allow for unforefeen accidents and expenfes, 10 per cent. upon the above -	457	4	10
	£ 5,029	13	4

N. B. No falaries or gratuities to engineers or furveyors are fuppofed to be included in the above eftimate.

Aufthorpe,
18th *June* 1771.

J. SMEATON.

P. S. I cannot be anfwerable for prices, for want of a fufficient knowledge of particulars at Dover, but the prices herein fet down are fuch as I think fhould rather exceed than fall fhort. But the quantities, being correctly eftimated, the whole is capable of being corrected by any perfon well verfed in the prices of work and materials at Dover.



AYR HARBOUR.

(See Plan, Plate 9.)

The REPORT of JOHN SMEATON, upon the Harbour of Ayr.

FROM a view taken the 2d September 1771, it appears to me that the harbour of Ayr which is near the mouth of the river Ayr, and which falling into the wide and open part of the Firth of Clyde, upon a flat coast with a drift fand, is by nature badly circumftanced for keeping open, having conftantly a bar before its mouth, as almoft all others in like circumftances are more or lefs fubject to; and were it not for the river Ayr, which being a river of middle fize, and fubject to great fpeats in rainy feafons, which drive the fands out to fea, that the furge with wefterly and north wefterly winds bring in and heap upon the entry of the harbour, it would be very fpeedily choaked up and deftroyed. Seeing therefore, that the fpeats of the river Ayr are in a manner the only means by which the harbour is kept open, it follows, that to improve the fame in depth of water, which is the prefent object, it is neceffary to attend to thefe circumftances, by which the force of the land waters can act with the utmoft advantage in driving off the fands, and to the forming and improving fuch artificial barriers as fhall have the moft direct tendency to prevent the effect of the winds in bringing it in.

Something for this purpofe has been done many years fince, in the erection of the north and fouth dykes or walls, to confine the channel of the river in paffing the flat fands, but not having been effectually executed, the depth of water in the harbour is not fo good as it might have been; however, though I have reafon to fuppofe when what I have to propofe is executed, that there will be a gaining of full three feet additional depth of water at a medium, yet as the action of the winds to bring in fands, and the floods to drive them out, are the two powers that are oppofed to one another, but as at different times and in different degrees, it follows that from the nature and operation of fuch inconftant forces there will always be times when the depth of water will be alternately greater and lefs.

The principal fault of the prefent dykes is their lownefs, which being in a great meafure covered at half flood, the fpeats are left unconfined from half flood to half ebb, whereby a material part of the power of the fpeats to fcour is loft. Another material thing, is, that the

the south dyke being so low, that the seas find a passage over a great part of it, even at one quarter of flood; and the sands appearing to drive coastways from the S. W. to the N. E. by the westerly winds, the south dyke does not prevent the sands from being washed over it into the channel of the harbour, and which must then remain till the speats come to drive it out again. Lastly as the north-west and northerly winds act very powerfully on the mouth of the harbour, and the seas having a long fetch from the north down the firth of Clyde, they have power enough to prevent the larger gravel that comes down the river from getting out to sea, and thereby form the north bank extending from the north pier to the north-west, so as to bar up the harbour entirely to the north, the bank being dry at low water, and forcing the land waters to take their course to the westward: when a number of large speats happen, this bank almost directly opposing the land current, the bank is driven out more to the northward, so as to admit the vessels to steer in from the N. W.; but by a series of northerly winds without freshes, this bank is brought closer in, so as to oblige the vessels to steer in from the W. by N. as it was when I saw it, and sometimes from the west, and as this is the direction nearly of the two present heads, vessels then going in with a scant wind, are apt to be driven upon the north pier.

The most obvious remedy for those evils in part is to build up both the south and north dykes up to high water mark, for by this alone a considerable part of the obstructions will be removed; the sands will be prevented from driving into the harbour from the south west and the speats and land floods being confined, they will act more powerfully upon the bottom, and therefore being preserved in one column till they pass the heads they will act more forcibly upon the north bank to drive it off, and by that means not only keep the Channel more to the north but also make deeper water over the Bar; it is not a matter of calculation to determine what additional depth will be hereby gained, but I should expect it to be not less than eighteen inches over the Bar.

The shape and position of the north bank shews how the powers of nature are balanced; and though it may be very desirable to force a passage right through the bank directly out to sea, yet this seems too great a thing to be attempted. I apprehend it better to conform to nature than attempt to force her, as I take it for granted it will be more desirable to have a good deep passage out at N. West than an indifferent and obstructed one at N. or N. N. West.

It was with a view doubtless of keeping the channel to the North, that the south dyke was carried out so much further than the north, but yet it has not this effect; for though the seas have power enough to keep up the north bank of such a height as to prevent vessels

vessels going over it, yet being covered at young flood, it is so low that speats find their way over it in so great a breadth, as not to be able effectually to remove it; by this means a great part of the force of the land waters is spent in a fruitless effort to do what they can never sufficiently accomplish to answer any good purpose; I therefore propose to turn their whole effect to such a quarter as by co-operating with nature they may act with full advantage, and thereby maintain the greatest depth of water possible in such a situation.

This will be done by lengthening out the north dyke or pier towards the west, as shewn in the plan, by which means the whole force of the back-water being spent in a N. W. direction, and the north bank prevented from being driven in by the seas into the harbour, I expect there will be more water over the bar than at present by at least three feet, and the direction in and out permanent to the best situation it is at present capable of.

The only objection I see to this prolongation of the north head, is that the N. West seas will fall right into the mouth, and carry a swell into the harbour; but as this harbour by the south point of the mull of Cantire and the north of Ireland is in fact land locked from every quarter, there never can be any very violent surges such as coasts open to the ocean are subject to; and the quay is so far upwards from the mouth, that what comes in will be in a manner spent before it comes to the place where the ships lie. However, I apprehend this will be the least of those evils the harbour is subject to; and in all artificial harbours, we have only the choice of the least evil.

The present irregularity of the north and south dykes makes it very difficult to form an estimate of the expense of compleating them; but taking it for granted that stone can be procured at the same price as that employed for the new coal quay, the best I can make will be as follows.

ESTIMATE for the Harbour of Ayr.

	£	s.	d.
The North Pier being supposed $16\frac{1}{2}$ chains long = 363 yards; and supposing half of this to want raising at a medium 4 feet high and 5 feet thick, will contain 403 cube yards at 7s.	141	1	0
To rubble for footing the present dyke, viz. 2 yards per yard running for the harbour side, and 1 yard per yard running for the outside, viz. for the whole length 1089 yards at 6s.	326	14	0

the fouth dyke being fo low, that the feas find a paffage over a great part of it, even at one quarter of flood; and the fands appearing to drive coaftways from the S. W. to the N. E. by the wefterly winds, the fouth dyke does not prevent the fands from being wafhed over it into the channel of the harbour, and which muft then remain till the fpeats come to drive it out again. Laftly as the north-weft and northerly winds act very powerfully on the mouth of the harbour, and the feas having a long fetch from the north down the firth of Clyde, they have power enough to prevent the larger gravel that comes down the river from getting out to fea, and thereby form the north bank extending from the north pier to the north-weft, fo as to bar up the harbour entirely to the north, the bank being dry at low water, and forcing the land waters to take their courfe to the weftward: when a number of large fpeats happen, this bank almoft directly oppofing the land current, the bank is driven out more to the northward, fo as to admit the veffels to fteer in from the N. W.; but by a feries of northerly winds without frefhes, this bank is brought clofer in, fo as to oblige the veffels to fteer in from the W. by N. as it was when I faw it, and fometimes from the weft, and as this is the direction nearly of the two prefent heads, veffels then going in with a fcant wind, are apt to be driven upon the north pier.

The moft obvious remedy for thofe evils in part is to build up both the fouth and north dykes up to high water mark, for by this alone a confiderable part of the obftructions will be removed; the fands will be prevented from driving into the harbour from the fouth weft and the fpeats and land floods being confined, they will act more powerfully upon the bottom, and therefore being preferved in one column till they pafs the heads they will act more forcibly upon the north bank to drive it off, and by that means not only keep the Channel more to the north but alfo make deeper water over the Bar; it is not a matter of calculation to determine what additional depth will be hereby gained, but I fhould expect it to be not lefs than eighteen inches over the Bar.

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This will be done by lengthening out the north dyke or pier towards the weft, as fhewn in the plan, by which means the whole force of the back-water being fpent in a N. W. direction, and the north bank prevented from being driven in by the feas into the harbour, I expect there will be more water over the bar than at prefent by at leaft three feet, and the direction in and out permanent to the beft fituation it is at prefent capable of.

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To

To making up the south dyke, being supposed 19 chains or 428 yards long, being supposed 12 feet thick at base, 5 feet at top and 10 feet high, will contain 4042 yards at 7*s*. - - - -	1,414	7	0
To lengthening the north dyke by an additional pier of 5 chains long or 110 yards, to be at a medium 15 feet base, 5 feet top, and 15 feet high, will contain 1833 yards at 7*s*. - - - - -	641	11	0
Neat estimate -	£ 2,523	13	0
Allow for contingencies at 10 per cent -	252	7	4
Total -	£ 2,776	0	4

N. B. The prices of the above estimate are formed upon the expense to me delivered of building the new coal quay on the north side of the river, after deducting the expense of timber and lime, which will here be unnecessary. The quantities in respect to length are taken from the plans of Mr. Gregg to me delivered, upon a supposition of its being laid down by a scale of 3 chains to 2 inches,* there being no scale annexed to the plan; but if I happen to have taken my measures from a wrong scale, the expense must be increased or diminished in proportion as the real measures turn out greater or less than I have supposed them.

Austhorpe,
22d *January* 1772.

J. SMEATON.

* This is commonly marked fifteen among the plotting scales.

HULL QUAYS.

REPORT on projected Quays at Hull, 17th April 1773.

Mr. Smeaton is desired to give his opinion upon the following question, viz.

SUPPOSING a platform or quay be advanced to the distance of fifteen feet beyond the fronts of the staiths or warehouses on the west side of the river Hull, within the town of Kingston upon Hull, from Hickson's staith south of Walton's ship yard north, to be supported upon piles, leaving the course of the river open underneath the said advanced wharf, or otherwise making the same up solid within the said advanced space:—Quære, whether this will have any, or what effect, upon the drainage of the carse lands and low grounds that discharge their water into the river Hull, above the north bridge of the town; and also whether it will have any, and what effect, upon the wharfing or jetties on the east side of the river opposite to the said advanced wharfs; on supposition also that docks for the reception of vessels are to be constructed in the town's ditches on the north west side?

The Answer of John Smeaton, Engineer.

Having carefully viewed the river Hull from the Holderness sluice, a little above the north bridge to the garrison jetty; and having perused the several reports of Messrs. Mylne and Robson, of Mr. Grundy and of Mr. Wooler, respectively; having also made diligent enquiries of those whom I esteemed best able to inform me; I beg leave first to lay down the following facts:—

1st. That when it is low water in the river Humber, the river Hull in the greatest land floods does not fill the channel thereof (within the space above mentioned) so high as half-tide mark, and then goes off with great rapidity.

2dly. That when it is high water in the Humber, the greatest land floods make a current of but very moderate velocity.

3dly. That the sea doors of Holderness sluice continue shut several hours during the time of high water, even in wet seasons.

 4thly. That

4thly. That the frontages of matter formed before the ftaiths and warehoufes fpecified in the above queftion, are at a medium uncovered to the breadth of fifteen feet and upwards at half tide.

N. B. As there was a confiderable frefh in the river, from preceding rains, on my view thereof, as well as a confiderable difcharge from the Holdernefs drain, the information whereon the three firft articles were eftablifhed was in a great meafure confirmed by my own obfervation, and the laft occurred upon my own view.

From the above I infer, that by the great declivity in the river in the above fpace, (which from former obfervations I make to be above four feet), notwithftanding the many obftructions therein, as all the natural flood waters are carried off in the bed of the river, without fwelling it fo high as the half or middle tide mark, the greateft obftruction to their getting away when above that level is the oppofition of the tide of flood from the Humber, which alone caufes them to rife above that level; and though the feveral impediments mentioned in the faid feveral reports, undoubtedly contribute fomething; yet thefe impediments altogether, when the furface of the river is above half tide mark, are fmall in proportion to the oppofition of the Humber's tide.

2dly. That the drainage of the Holdernefs and other carrs muft neceffarily be carried on principally while the river Hull is under the half tide mark, that is from half ebb to half flood; and confequently, as during this time a projection of fifteen feet from the fronts of the ftaiths above mentioned, would reft on ground that in general would be uncovered by the water; the drainages above mentioned would fuffer no fenfible change, whether the faid projected ftaiths are built up hollow on piles, or folid with walls.

3dly. Since the velocity of the water of the river Hull, within the fpace above mentioned, is very much flower when above the level of half tide than when below it; and fince it is a known fact, that the fcouring of rivers by land floods chiefly takes place when they run over the beds of the rivers at low water, it follows that the projection aforefaid, whether folid or otherwife, will make no alteration in the action of the river upon the wharfing or jetees on the eaft fide.

I am therefore of opinion, that the propofed projection of 15 feet cannot be of detriment to either the drainage of the low grounds into the river Hull, nor to the wharfing or jetees on the eaft fide of the river, even if made folid, but if built on piles, this appears to me to

to take away all colour of objection; and in cafe a wet dock for the reception of fhips and veffels be made in the town's ditches on the north weft fide of the town, as this will proportionably diminifh the number of veffels that now lie as obftructions in the ftream of the river at low water, the obftructions upon the whole muft be leffened, efpecially at the time of low water, when every impediment to the free courfe of the river is of the moft confequence to the drainage and fecurity of the faid wharfs and jetees.

Hull,
17th *April* 1773.

J. SMEATON.

An APPENDIX to the REPORT of JOHN SMEATON Engineer, upon the propofed Quays and Docks at Hull, 17th April 1773.

BEING called upon this bufinefs without previous notice, and being through want of time obliged to deliver my opinion with more brevity and lefs explanation than I otherwife fhould have done; being alfo lately called to meet Mr. Grundy at Hull, who was invited to give his opinion upon a propofition of the fame nature, as that which formed the fubject of my report above mentioned; I have on this occafion had a further opportunity of extending my obfervations, and converfing with Mr. Grundy upon the nature of the cafe; and having alfo the pleafure to find, that when the fame propofition is ftated to each of us, we do not materially differ in our conclufions; yet as each of us has proceeded in his feparate report, to form his opinion by a mode of reafoning fomewhat different; we find it will be more eafy to ourfelves, and more fatisfactory to our employers and all concerned, to deliver what we have further to fay, according to our own words and conceptions: And I find no reafon now to deviate from any material fact or opinion contained in my faid report of the 17th April laft; what I now offer I fhall confider as an appendix to that report, and in further explanation and confirmation of the conclufions therein contained.

In Mr. Grundy's report of the 14th October 1773, he has given the admeafurements of Hull harbour or haven from the outlet thereof at the garrifon jetee to the north bridge, at thirteen different places; which dimenfions, as I doubt not of their having been taken with all due care and fidelity, I beg leave to refer thereto, and found myfelf thereupon. The firft and the two laft of thefe admeafurements lying without the limits of the propofed undertaking, I put on that account out of the inveftigation of a mean fection of the harbour.

I think

I think it right, however, to take the ſeveral capacities within the limits above mentioned altogether, and draw the medium from the whole; and not from the moſt contracted places only; becauſe the ſeveral parts can obſtruct more or leſs, only in proportion to the contraction along each ſpace reſpectively, the ſum of all the obſtructions being made up of the ſum of all the parts taken ſeparately.

The meaſures oppoſite the three interior jetees, contained in numbers 3, 5, & 7, being contractions of a peculiar kind, without appearance of real utility, I claſs them by themſelves, and then taking a mean of all the remainder, viz. 2, 4, 6, 8, 9, 10, & 11, I find that by proceeding to draw a mean ſection therefrom, in a manner ſimilar to that whereby Mr. Grundy has obtained a mean ſection of the narroweſt places in his report.

	feet.	inches.
The mean high water line will be - - -	195	6
The low water - - - -	112	6
The depth at low water - - -	5	9
And the total area of the ſection - - -	4100 ſq. ft.	

Proceeding in like manner with the three ſets of dimenſions at the ſaid three jetees, the mean dimenſions will be, viz.

Mean width at high water - - - -	168	6
Ditto at low water - - - -	102	9
Mean depth - - - - -	5	3
Mean area of the ſection - - - -	3573	

Now, as theſe things at preſent ſtand, thoſe jetees have their ſhare in obſtructing the current of the water; and ſuppoſing their influence equally extenſive as the former, (which is more than there is need to allow), the mean ſection of the harbour as it now ſtands will be the mean of the areas of thoſe two mean ſections.

The whole will ſtand thus:—

	feet.
The mean or average ſection of the harbour, excluſive of the jetees -	4100
The mean or average ſection of ditto at the jetees - -	3573
The difference - - - - - -	527
The mean of the average - - - -	3836

So

So that 3836 feet I conſider as the mean ſection of the harbour, as it now ſtands, when clear of ſhipping; and if from this we deduct what Mr. Grundy has deducted for the mean or average ſections of four ſhips lying abreaſt in this harbour, viz. 448 feet, we ſhall then have a neat mean ſection, with the ſhipping, viz.

	feet.
Neat ſection of the haven, clear of ſhips - - -	3836
Deduct at a medium for ſhipping - - - -	448
Remains clear water way, with the ſhipping - - -	3388

The ſection of the propoſed projection of fifteen feet for a ſufferance quay, if made ſolid, will, as I compute it, occupy $152\frac{1}{2}$ feet of the area above mentioned, which is ſcarce $\frac{1}{23}$d part of the whole ſection, with the ſhipping therein, ſo that

	feet.	inches.
Deducting from the above area - - - -	3388	
The whole ſection of the quay - - - -	152	6
There will ſtill remain after the quay is made, clear - -	3235	6

Mr. Grundy has in his report alſo given the admeaſurement of the river Hull in ten different places above Hull bridge, from whence and from the before cited admeaſurements it appears, that the ſaid clear ſection of $3235\frac{1}{2}$ feet, mean ſection of the river before the propoſed quay, ſuppoſing all impediments to remain, is yet larger than any clear ſection of which the admeaſurement is given above the ſaid propoſed quay; the largeſt of them all, viz. below Holderneſs new clough, which is below the outfall of all the drainages, Mr. Grundy has now accurately computed to be 2969 feet, that is $266\frac{1}{2}$ feet leſs than the mean ſection oppoſite the projected quays. If therefore the ſaid largeſt ſection of 2969 feet taken below all the drainages, is eſteemed ſufficient, no detriment can be apprehended from the propoſed quay, as it leaves a clear water way of $266\frac{1}{2}$ feet more than ſufficient; but as I apprehend this argument, though juſt, is inconcluſive, upon the principle of my own reaſoning, viz. that every ſection of a river is more or leſs an impediment to the currency of water; ſo that as impediments they only differ in quantity, as the ſection is relatively greater or leſs, the ſum of all the impediments being the ſum of all the particular parts as above ſtated; we will therefore now examine the matter as to the queſtion.

At the time of high water of a high ſpring tide with a great land flood in the river, when it is ſuppoſed the river riſes to the height of twenty-two feet above the ordinary low water

water line, in which ſtate the ſections above referred to are ſtated by Mr. Grundy and myſelf; it is allowed that in this ſtate the quay will occupy 152$\frac{1}{2}$ feet of the ſection, being at a medium $\frac{1}{13}$d part of the whole nearly; but at the time of high water even in the greateſt land floods, the water being then in Hull haven nearly ſtagnant, it cannot in that ſtate be any impediment at all; for were there a ſheet of piling acroſs the river, while the water continued ſtagnant, it could have no effect. At low water alſo, as the greateſt land flood would be below the face of the quay, as the ground now lies, it then can be no impediment; the impediment, if any, muſt therefore be the greateſt at ſome point between high water and the time that the tide leaves the face of the quay, which in the ordinary ſtate of the river will be at or very ſoon after half tide; and from a computation that I have made for this purpoſe, in which every circumſtance is exaggerated in diſfavour of the quay, it can never have the effect of cauſing the water to ſwell at the head of the quays above $\frac{3}{4}$ an inch; and as this will be when the water has ſubſided below high water about 7 feet, ſo that the ſwell of $\frac{3}{4}$ an inch at that time cannot be ſuppoſed to have any effect upon the running off of the water in the ſuperior parts of the river, or ſo minute a one that it eſcapes calculation to ſay what it is.

With reſpect to the diſcharge of the land flood waters, as affecting the barrier banks of the adjacent lands, it is evident that the pinch of the whole affair is at high water, when it has been ſhewn that the water being ſtagnant, the impediment is reduced to nothing: again, as the internal drainage ſluices muſt do the greateſt part of their buſineſs after the water has left the face of the quay, its impediment to them is reduced to nothing alſo; or to ſo very minute a quantity as to juſtify the opinion I have already given in my report of the 17th of April laſt, that the propoſition of 15 feet cannot be of detriment to the drainage of the low grounds into the river Hull, or to the wharfings or jetees on the eaſt ſide of the river, even if made ſolid.

However, as it may be expected by the proprietors of land, and deſired by the promoters of this undertaking, that every cauſe of apprehenſion, however minute, ſhould be intirely removed or fully compenſated, it will follow, that if an addition of water may be made equivalent to 152$\frac{1}{2}$ feet, that this will at all events counterbalance the ſuppoſed obſtructions; and if the ſaid addition of water-way is of ſuch a nature as to operate during the whole time of tide, or when the water is at a lower level than the ſaid quays can impede, inſtead of a detriment this muſt be conſidered as a benefit.

Now, if but a ſingle row of veſſels that now lie in the harbour are ſuppoſed to be moved into the wet dock, and ſuppoſing them at a medium to occupy an area equal to 20 feet wide, and

and 8 feet deep, this produces 160 feet, which will equally operate at low water as at high; and as it is probable that the dock will entertain as many ſhips as will amount to a double and even a treble tier in the harbour, it will follow that the circumſtance alone of transferring a part of the ſhipping to the dock, will be a moſt full and ample compenſation for any impediment that can be ſuppoſed to ariſe from the projection of the quays, even if they were made greater than now intended.

A further advantage will probably ariſe from the removal of part of the matter before the face of the quays, that according to the preſent ſection now lies there; for as the ground is too ſteep for ſea veſſels to lie upon, it will certainly be the intereſt of the proprietors to remove it, in order that large veſſels may unload at the quay ſide; this will undoubtedly be gradually done, and will add to the ſection of the River towards the bottom, where one foot will be of more ſervice than two near the top.

It is alſo to be remarked, that the difference of the mean ſection of the haven at the jetees and clear of them is no leſs than 527 feet, which is a quantity above three times greater than the ſuppoſed addition by the quays. It appears to me that thoſe jetees are of no uſe, but on the contrary an impediment to the harbour, and that they may ſafely be taken away, or at leaſt in the greateſt part; and in caſe that can be effected without objection, I recommend it to be done, not only as an improvement to the harbour, but as of itſelf much more than an equivalent to any impediment that can be ſuppoſed to ariſe to the drainage from the quay.

The North Bridge is alſo another ſubject of improvement to the paſſage of the water; as upon tide of ebb from the multiplicity of timbers and obſtructions there is a ſenſible fall here, and as the ſpaces between the croſs rows of piles for ſupporting the dormant part of the bridge ſeem filled with ſtones or ſome kind of hard matter above the bottom of the river, thoſe being removed will increaſe the ſection in this, now the moſt obſtructed part.

As it ſeems neceſſary to make a communication with the Humber by draw gates from the wet docks, it will be practicable on extreme of floods to give paſſage to part of the waters of the river Hull that way; and upon emergencies there is no doubt but that this will be done, as it may be without detriment to the works; but as the Humber's tide at high water will equally oppoſe the paſſage of the waters by way of the dock as by way of the river, its motion will become ſo ſlow till it is got down to ſuch level, as the gates can be no longer permitted to ſtand open, that in general its benefit to drainage can be ſo ſmall as

as not to demand, what on every account ſeems ineligible, viz. for the drainage to have command over the gates of the dock.

Upon the whole matter, having with Mr. Grundy carefully viewed and examined the ſtate of the channel of the river between Fore Dyke and Hull Bridge at low water, I am of opinion that the obſtructions in the channel of the river, particularly from Scullcoats Church to Hull Bridge, are ſo many and ſo great, that even if the river Hull from Hull Bridge to the Humber were dug as wide and as deep as the Humber itſelf, yet the drainage above Scullcoats would remain in nearly the ſame ſtate as at preſent, till thoſe impediments between Hull Bridge and Scullcoats were removed.

On examining alſo with Mr. Grundy the ſtate of the bottom of the river between Hull Bridge and the South End, I find that the bottom of the river in every place, where the crowded ſhipping would permit a trial to be made, is compoſed of ſtones, and ſo hard compacted together, even in the middle of the river, that I did not find it practicable to pierce through it with a ſpit; this continued nearly the ſame till we got down oppoſite to the loweſt of the three internal jetees, viz. Church Lane jetee, where in the middle of the river we firſt began to loſe the ſtone, and below this (it being here the wideſt part of the harbour) we found the bottom a watry ſand or ſilt, but yet ſtones on the wharfing on each ſide; from whence I conclude as before; that as the principal rapidity of tide of ebb will be when the water is below the face of the quays, that the eaſtern wharfs and jetees will be unaffected thereby; and that were the current much ſtronger than it is, it could make no impreſſion upon the bottom of the river above Church Lane jetee, and below from the increaſe of width the current has a leſs tendency to make an impreſſion, which tendency will be ſtill prevented at the ſides by the ſtones, in like manner as now that the three internal jetees by diſturbing the regular ſet of the current are of diſſervice to the wharfing taken collectively; and if thoſe jetees were removed, the ſtones will remain a better defence to the wharfing than in the preſent ſtate.

J. SMEATON.

Auſthorpe,
18th *December* 1773.

HULL DOCK.

The REPORT of JOHN SMEATON and JOHN WOOLER, Engineers, upon the ſeveral Matters referred to their Conſideration by WILLIAM WALKER, Eſq. Chairman to the Commiſſioners of the Dock Company at Hull, by his Letter dated the 14th Auguſt inſtant.

HAVING carefully viewed the ſeveral matters referred to our conſideration, ſo far as the preſent ſtate of the works would admit, aſſiſted by the information of Meſſrs. Holt, Turner, and Weſterdale, we are of opinion as follows:

1ſt. Reſpecting thoſe parts of the dock wall that are bilged out of their line, containing a length of 187 yards, or thereabouts, we are informed that the ground upon which they ſtand was not only more ſoft and ſpungy than any other parts of the dock, but that part being raiſed the latter end of a ſeaſon which turned out rainy and wet, the maſonry had never an opportunity of drying or ſetting to that degree of firmneſs that otherwiſe it would have done; and further, it appears to us by the report of Mr. Holt, as to the depth at which the whole was founded, videlicet, nearly even with the excavated bottom or baſon of the dock, that the greateſt cauſe of failure in this part was the not going to a ſufficient depth below the general bottom in this ſoft ſtratum, ſo that the weight or reſiſtance of matter before the foot of the wall might be a ſufficient counterpoiſe to prevent the bottom from preſſing forwards, and at the ſame time raiſing the ground before it. And as this appears to us to be a radical defect that cannot now admit of an adequate remedy, we ſee no certain method of preventing its going further, but that of taking down the whole length ſo bilged, and new founding it upon ſafer principles; but as this will be attended with a conſiderable loſs of time, as well as of expenſe, we ſubmit the following conſiderations to the Board:—

In the firſt place, we are willing to think that this derangement would not have happened, if the bottom and ſides of the baſon had been charged at that time with the weight of water intended to be pent therein; that is to ſay, had the dock been full of water. Secondly, we are of opinion, that the letting in the water, and keeping it pent up to its proper height, may afford the means of preventing this bilging from increaſing, and in all probability would have the deſired effect, were the dock always to remain ſo filled, or always with a conſiderable depth of water therein. Thirdly, that the greateſt danger to be apprehended will be, when the water on account of any neceſſity or otherwiſe

wiſe is let out again, and as we cannot take upon us to ſay that this part of the wall would come down, or fail upon ſuch a retreat of the water, we therefore cannot help recommending it to the Company, as every thing ſeems nearly ready for the trial, and nothing appears to us to forbid its being done, to put this matter to the teſt; for if any part of the wall ſhould fail thereupon, it can be nearly as well rebuilt as now, and if it ſhould thus bear the teſt, much time and expenſe will be ſaved. On this head therefore we beg leave to remark, that it would be proper to introduce the water ſo gradually, that it may for example be a week in filling, which may be done by plug holes cut through the frame dam. Afterwards to let the water remain at its full height for a fortnight at leaſt, ſo as to give time to the earth that backs the walls to ſettle and conſolidate, and then to let it out, not all in one tide, or ſo faſt as the tide ebbs, but to bring the ſtrain or ſtreſs upon the walls by degrees, allowing, for example, to ebb out five or ſix feet the firſt day; the ſecond to let it ebb out as low as the former; and after this, in the courſe of the receſs of the tide to let off by the draw ſhuttles in the lock gates about three feet more; and thus day by day making the reduction by two and a half or two feet, till either the whole is let off that will go out, or that ſomething ſhall appear to prohibit it; ſo managing the water diſcharged by the ſhuttles, as to take all the time in each tide poſſible, ſo as only to be drawn down to its intended gage by the time the tide has reflowed nearly to the ſame height.

It is to be remarked, that in one place in this damaged wall, for about twenty feet in length, near the greateſt ſwell of the weſtern bilge (where the top of the wall is got out of the line two feet eight inches and a half), that the bottom part below the off-ſets is further bilged and ſeparated from the internal part; which part being of conſequence weaker than the reſt, we wiſh to recommend, by way of giving it an equal chance with the reſt, that after the water is let in, and the frame dam removed, to form an artificial buttreſs againſt it, by dropping down Hazlecliff ſtones, brought into the dock by lighters, ſo as to form a ſlope againſt the wall higher than the ſet-off, this buttreſs by its weight will preſs equally againſt the wall, and prevent the bottom from riſing; and ſhould the whole by this means ſucceed, and theſe ſtones be found materially in the way, they may be afterwards removed, and the place otherwiſe ſecured in ſuch a way as to be leſs liable to objection on that account; at any rate this place may be avoided without loſing more than one birth by the quay ſide.

In regard to the reſt of the wall round the dock, having the advantage of better ground, and being got up in better ſeaſons, it appears to us to ſtand as it was built, without crack, or any apparent failure; we therefore apprehend and expect that it will prove ſufficient, obſerving at the ſame time, that the whole is in our opinion defective in

not having the buttreſſes or counter-forts much nearer together; in conſequence hereof, ſo great a ſtreſs lies upon the preſent ones, as in the bilging parts of the walls to have produced a thorough ſeparation between the wall and buttreſs. There alſo appears a deficiency in the walls, in the omiſſion of a proper quantity of throughs or large bond ſtones which ought to have been diſtributed throughout at due diſtances, in order to tie the brick-work properly together. We alſo beg leave to mention another diſadvantage attending them, and that is, in not ſeating their baſes or foundations a couple of feet or thereabouts, deeper in the ground, or in other words, below the general bottom or floor of the baſon, in order to afford them the proper abutment or balance, when their weight joined to that of the earth they retain, comes to act with full force thereupon.

The ſecond point referred to in the above letter is the riſing of the floor of the lock in the middle, which we beg leave to obſerve ariſes from a natural cauſe, and will neceſſarily do ſo, more or leſs, according to the firmneſs of the ground upon which it is laid, and the ſtrength of the timbers which compoſe it, joined with the perfect ſtability of the wing walls which form the lock. From the information of Mr. Holt, as to the ſcantling and diſtribution of the timbers employed therein, we are of opinion, that the floor is too ſlight for ſo maſſive a piece of work, which occaſions it to ſpring more than it otherwiſe would have done. This ſpring or riſing is in general about two inches at or near the threſhold of the gate where the floor is double, but in the ſingle floor of the chamber it is about three inches, but in the aftermoſt or ſtern-gate receſſes, where the breadth or width of the floor is ſix feet greater, the ſpring or riſing is four inches. We are therefore willing to hope the whole floor may remain or continue as it now is, and that no further inconvenience is to be apprehended therefrom, than what regards the facility of opening and ſhutting the gates. We had them tried, and found the north of the head gates, and ſouth of the ſtern gates, move ſomewhat ſtiffly, yet as the letting in of the water will be likely to produce an eaſement, both by ſetting down the middle of the floor, and buoying up the gates, we cannot recommend an alteration till the whole is tried, and then it is poſſible ſeveral things may be better remedied than they can ſpeculatively be foreſeen. Reſpecting the walls of the lock they have the appearance of being well built; we however obſerve ſome ſmall ſets therein, which we impute to the want of ſtrength in the foundation timbers.

Thirdly, to make the entry into the harbour, as eaſy and convenient as poſſible.

We have made a rough ſketch of the ground adjacent to the entry, and apprehend, that to make all poſſible convenience the Dock Company ſhould be poſſeſſed of Mr. Walton's ways or frontage before his wharfs into the river.

In

In anſwer to the fourth, regarding what is further to be done for the completion of the plan, we apprehend that the dock in its preſent ſtate is wanting in ſome eſſential matters, the principal of which is the means of ſcouring it from the ſilt that will undoubtedly gather therein, by taking in the muddy tides from the Humber. Had the lock been made with gates pointed both ways, that is, towards the river as well as to the land, ſo as to ſhut out all ſuch ſpring tides as would riſe above the gage height of the conſtant water in the dock, much of this would have been excluded; alſo the depth of the dock being ſuch as to retain four feet at low water, and being in breadth 255 feet, we are of opinion that no ſcowers from any practical reſervoirs can take place, ſo as to clear the ſilt into the Hull, it therefore remains, that by introducing the current of the river Hull at low water, (and particularly when there happens a freſh in the river at ſpring tides in the ſummer), to paſs through the dock by means of a canal down towards the Humber, this clearance with the aid of men may be effected, which canal muſt be dug to a depth at leaſt equal, or indeed rather of ſuperior depth to that of the dock, with ſuitable ſluices or locks thereon.

The four draw-gates now formed in the croſs wall at Beverly Gates, amounting together to a breadth of fifteen feet only, we look upon as inſufficient to let all the current from the river Hull paſs through, that may be introduced to advantage, unleſs ſuch a pen and fall be brought on at that place as would materially injure the declivity of the current in its paſſage through the length of the dock, and in conſequence the ſtrength of the ſcower. There being therefore a neceſſity for the removal of this wall, we would adviſe a ſluice to be erected of equal depth with the preſent great lock, or indeed ſomewhat deeper, with a ſingle pair of gates pointed towards the dock, and a draw bridge over it, for the Beverly roads.

At Myton Gate it will be ſufficient to conſtruct a bridge only of ſufficient paſſage for the water, and at Hazel Gate a ſluice of ſome kind, alſo of ſufficient water paſſage, with a bridge over it. If this be made a navigable paſſage even for ſmall veſſels, ſome of them, ſuch as the large keels from Thorn, &c. that cannot ſtrike their maſts, will render it proper that the bridges at Hazel and Myton Gates, ſhould alſo be draw or moveable bridges, and we would recommend that the ſluice at Hazel Gates, if made a navigable ſluice or lock, ſhould be conſtructed with double pairs of gates, pointed both to landwards and ſeawards; and we look upon it that a navigable ſluice at Hazel Gates would be found very convenient for the following reaſons:—

When a conſiderable trade comes to be eſtabliſhed upon the baſon, we apprehend it will be found very troubleſome to open the great lock for the paſſage of keels, lighters, and

and ſmall veſſels, as well as reduce the water of the baſon in neap tides. This defect may in ſome meaſure be ſupplied by conſtructing a proper lock for ſuch veſſels to paſs in and out at the Hazel Gate, which if laid one foot deeper than low water at the Humber, will afford a ſufficient paſſage for the ſcower water, if made eighteen feet wide, but may be made as much wider as ſhall be thought neceſſary for the convenience of trade.

Now, as there will be but about five feet of deſcent of the ſurface of the water from the entry of the dock at the river Hull, to its paſſage out into the Humber oppoſite Hazel Gate, we look upon it that its velocity through the dock will of itſelf be too feeble to drive out the ſilt, it will therefore require to be aided by ſetting in a large number of men with col-rakes and other inſtruments to raiſe the mud and ſilt, as many tides, once or more in a year, as ſhall be found ſufficient for the purpoſe of getting rid of the intermediate accumulation; beginning in the middle, and going as near the ſides as ſhall be judged convenient to the ſecurity of the walls, for the middle being cleared to a ſufficient extent, the grounding of veſſels near the ſides will continually be preſſing down the mud from the ſides towards the middle.

It is to be noted, that nothing but the preſent dock baſon will require the aid of men to raiſe the mud; the external paſſage from the lock to the river Hull, as alſo from the propoſed ſluice at Beverly Gates to the Humber, may be kept clean by ſcowers from the great baſon.

We muſt conclude with remarking, that, with regard to the keeping the great baſon clear of mud, there is doubtleſs a poſſibility of doing this by machines worked by men and horſes, properly contrived for the purpoſe; and though doubtleſs this labour will be very great, and at the ſame time an almoſt continual incumbrance to the baſon, yet as on the other hand the charge will be very great for the additional works above propoſed, it might be wiſhed to bring the matter to a computation; but as it would take up a conſiderable length of time to enter into a detail of this buſineſs, which would be neceſſary for the purpoſe of an eſtimate, we muſt beg leave to poſtpone the conſideration of this matter to ſome future opportunity; and indeed till the trial that we have already mentioned to be made of the dock ſhall ſhew for a certainty what works it will be moſt needful for the company to take in hand.

J. SMEATON.
JOHN WOOLER.

Hull,
17th *Auguſt* 1778.

To the Honourable the Commiſſioners of the Cuſtoms, and the Chairman of the Dock Company of Kingſton-upon-Hull for the time being.

Hull, 24th November 1779.

WE, the underwritten perſons being ſeverally appointed by the Honourable Commiſſioners of His Majeſty's Cuſtoms, and the Chairman of the Dock Company of Kingſton-upon-Hull, in purſuance and by virtue of an Act of Parliament made in the 14th year of the reign of his preſent Majeſty George the Third, chap. 56, for making and eſtabliſhing public quays and wharfs at Kingſton-upon-Hull, having carefully ſurveyed and examined the ſundry works executed by the ſaid Company in purſuance of the above mentioned Act, humbly beg leave to report as follows:

1ſt. That in conformity to the clauſe, page 9 of the printed Act, directing the works to be done, the ſaid Company have made the baſon or dock with a large ſea lock, or double ſluice thereupon, for the commodious paſſage of veſſels, in the whole extending from the river Hull to within twenty yards of the road, formerly paſſing through Beverly Gate, being as near to the ancient ſcite thereof as in our opinion it conveniently could be.

2dly. They have dug, and made the ſame in all neceſſary parts within fifteen inches of the depth of the bed of the river, as we found it at, and near to the entry into the baſon from the ſaid river, and that it now continues of the ſame depth except in ſome places near the entrance of the ſluice and baſon, where the mud has gathered, but which can be cleanſed away whenever the ſame ſhall become a real inconvenience or impediment, and which as we apprehend comes under the clauſe for cleanſing, page 13 of the ſaid Act to be quoted bye and bye.

3dly. That the ſame is capable of admitting loaded ſhips of great burthens, as it will receive upwards of twenty feet depth of water in ſpring tides, and as it ſtands at preſent, will retain by means of the lock or ſluice eighteen feet or thereabouts.

4thly. And that the width or breadth of the baſon or dock (excluſive of the ſluice and entry which are of neceſſity contracted) is of a medium of above ſixty feet greater than it could have been if the Company had not purchaſed ground beyond the limits which the ground granted by this Act from his Majeſty would have admitted.

5thly. That

5thly. That the ſaid Company have built a commodious quay or wharf, ranging along the ſide of the ſaid baſon or dock next the town, which as it appears to us is of a ſufficient and convenient length for the trade and buſineſs of the ſaid town and port, and which we can the more readily judge ſo to be, becauſe it is not only of the full length required by the ſaid Act, but of a greater length by above thirty feet than it could have been made had not the Company purchaſed the additional ground aforeſaid on the oppoſite ſide, being now of the width or breadth of ſeventy feet.

6thly. That reſpecting the conſtruction of ſuch "reſervoirs, ſluices, bridges, roads, and works, requiſite matters and things as they (the ſaid Company) ſhall from time to time judge neceſſary for the more convenient uſe of the ſaid baſon and dock," as directed in the 9th page of the ſaid Act, it appears to us that the Company have done ſuch of the above articles as are at preſent neceſſary for eſtabliſhing the trade and commerce intended by the ſaid Act, upon the ſaid baſon or dock, and the ſaid quay or wharf adjoining, and that the ſaid trade now is, and has been for ſome months paſt, carried on with convenience.

7thly. With reſpect to ſuch of the above diſcretionary articles, as further time and experience ſhall ſuggeſt to the ſaid Company to be neceſſary, for cleanſing or repairs of the ſaid baſon, quay and works, as it is directed by an expreſs clauſe, page 13 of the ſaid Act, as follows: "That the ſaid Company ſhall from time to time and at all times hereafter well and ſufficiently repair, maintain, ſupport and cleanſe the baſon or dock, and the quay or wharf, and all other the works, matters, and things by them to be made, built, and provided by virtue of this Act;" it ſeems to us that the manner of performing the ſame is left to the diſcretion of the ſaid Company, whenever it may become neceſſary.

Laſtly. That the public being now in poſſeſſion of the object required by the act to be done, and within the limited ſpace of ſeven years,—we do therefore report and adjudge that the works of the ſaid baſon and dock, and quay or wharf, are completed according to the intent and meaning of the ſaid Act.

JOHN WOOLER.
J. SMEATON.

WORKINGTON HARBOUR.

The REPORT of John Smeaton, Engineer, upon the Improvement of the Harbour of Workington in the County of Cumberland.

IN conſequence of a view and neceſſary admeaſurements taken of the harbour of Workington upon the 25th and 26th days of November 1776, at the inſtance of Sir James Lowther Bart. I have conſidered the ſame, together with the ſix firſt articles of a paper delivered by the gentlemen of Workington, to the following Purport, viz.

The gentlemen of Workington having taken their harbour into conſideration, think that it ought to be enlarged as well as repaired, and for that purpoſe wiſh to have an Act of Parliament.

What they chiefly want, is,

1. To extend the frame work down the north ſide of the river Derwent.

2. To repair, join, and preſerve the quays on the ſame ſide of the river, and to give powers to fix poſts for mooring veſſels, &c.

3. To ſecure the river Derwent in its preſent courſe ſo far as may concern the harbour.

4. To repair and extend the middle or merchants quay, and fix poſts thereon for mooring veſſels, &c.

5. To cut open, widen, and cleanſe the ſouth gutt, or mill race, as far up as to a point twenty yards northwards from the north corner of John Smith's houſe at the low end of the town; and between the ſaid gutt and a breaſt-work or quay, which is intended to be made between the eaſt end of the preſent ſouth quay and the ſaid houſe; and to take off the marſh twenty yards broad along the breaſt-work or quay already made and to be made between the ſaid houſe and the low gutter, for ways, moorings, lading and unlading ſhips, &c.

6. To make a mole on the ſouth ſide of the river, to break the force of the ſea, and to extend the quay down the Rectory ground to the ſaid mole.

Having therefore conſidered how far Sir James Lowther's intereſt and property may be affected by the above propoſition, as well as what may be proper to be done for the good of the whole, I am of opinion as follows:

1ſt. To the firſt propoſition there appears this objection; that by extending the frame work down the north ſide of the River Derwent, being nearly in a direction N. W. by the compaſs, and the great Seas that affect this harbour the moſt being thoſe from N. W. to S. W. all thoſe ſeas will be catched by the ſaid extended frame work, and will range alongſide the north quay in a more violent manner than hitherto they have done, there being no beach on that ſide for them to break and ſpend themſelves upon, ſo that the births of the ſhips lying to load coals, &c. at the north quay and hurries thereupon, will be rendered more unquiet than at preſent, and which are now the moſt uneaſy ſituations of any part of the harbour; and not only this, but at the ſame time Sir James Lowther will be precluded from making a very capital improvement, by an additional harbour on the north ſide.

2d. To the ſecond propoſition I muſt obſerve, that this being the property of Sir James Lowther, it is his buſineſs to execute: nor can I apprehend that Sir James can reaſonably object to ſuch poſts being fixed upon the quays on the north ſide of the river, as may be proper and neceſſary for occaſionally hauling ſhips in and out of the harbour; and from the quays on the ſouth ſide, provided the places of thoſe poſts be previouſly aſcertained, and limited in ſuch manner as not to interfere with ſuch improvements as Sir James Lowther may think proper to make upon the ſaid north quays and his property there.

3d. To the third I do not ſee any reaſonable objection, provided it be done ſo as not to interrupt the free courſe of the river Derwent.

4th. To the fourth the ſame obſervations occur as to the ſecond.

5th. To the fifth I do not ſee that Sir James Lowther can have any reaſonable objection, except any ſhould ariſe from matters of property that do not pertain to conſiderations of engineery.

6th. I alſo ſee no objection on the part of Sir James Lowther to the works propoſed in this article, provided the head of the ſaid mole be terminated at the place marked out in the plan for the termination of the ſaid mole or pier on the ſouth ſide, which place is nearly the ſame as where a heap of ſtones were placed, which were ſhewn to me as put there by the direction of the gentlemen of Workington for marking the place of the head or termination of the ſaid intended mole; and provided nothing be contained in the act to prohibit Sir James Lowther from building a mole on the north ſide, whoſe head or termination ſhall be reſpecting that on the ſouth ſide, the ſame as is ſhewn in the plan, that is, in a direction nearly N. E. and S. W. from each other by the compaſs, and at a diſtance not exceeding 200 feet.

I come now to deſcribe the improvements that I would propoſe to be made by Sir James Lowther on the north ſide; and look upon it that the ſpace propoſed to be incloſed by the new projected pier on the north ſide will be the moſt proper; and which appears to me by far the moſt improvable and eligible ſituation; for, from the ſoundings taken, there will be here nearly three feet more water than can be eaſily obtained in any ſituation further up the river, which is indeed a very material conſideration, becauſe at common ſpring tide there may be made here by deepening the ground as per eſtimate full ſixteen feet water, and as the neaps are ſaid to run about four feet lower than the ſprings, there will then be full twelve feet water, equal to the draught of the largeſt veſſels that now frequent Workington harbour as I am informed; an advantage either to the movement of the preſent veſſels, or to the reception of larger that I need not inſiſt upon.

As the bringing out a new mole from the land at high water mark will of itſelf be a work of conſiderable expenſe, it ſeems proper, in order to reap all the advantage that may be from it, to give the area incloſed a competent breadth. The breadth incloſed here is propoſed of about 200 yards, which ſeems ſufficient to contain every improvement that can at preſent or in future be requiſite at this place.

This diſpoſition will alſo be a very conſiderable improvement to the ſtillneſs of the water at the preſent quays; for inſtead of the ſeas after they have entered the outward heads ranging along the face of the north mole, as would be the caſe if the frame work were continued to the ſame point; by the ſpace being left open between the propoſed north head, and the preſent termination of the north frame work, the weight of the ſea will in part fall in there, and ultimately meeting a ſloping beach, will there be broken and ſpent, inſtead of being reflected from one object to another, as is in a great meaſure at preſent the caſe.

Furthermore,

Furthermore, the ſeas after paſſing this ſecond opening, finding ſo very conſiderable a ſpace to be expended in, the veſſels arranged alongſide the interior face of the pier will lie in a quiet harbour, and in ſailing in they will conveniently bring up by coming upon the ſloping ground of this new harbour, and this I apprehend is the whole of what may be originally done: But if the ſpace comprehended between an interior wharf wall, and the N. E. ſide of the pier, be dug out to the greateſt depth propoſed, and thus ſeparated from the reſt of the ſloping bay, the ſeas that will be propagated through this laſt contracted entry, will be ſo broken and diſperſed, that the veſſels will lie comparatively ſpeaking as ſtill as in a pond; while the outer bay or harbour will remain ſuſceptible of any other improvement that may hereafter be ſuggeſted; and in the mean-time be a receptacle for ſmaller veſſels occaſionally coming in to take refuge.

It is a poſſible thing, though not certain, that the ſands that drive coaſtways from S. W. to N. E. may in part get between the outward heads, and meeting ſtill water within the opening between the north pier head and the termination of the frame work may ſubſide and lodge there; and being out of the courſe of the Derwent at low water, cannot be driven out thereby: for remedy whereof, if this ſhould prove to be the caſe, I would propoſe to conſtruct an under-ground tunnel of five feet wide, to communicate the head of the interior harbour with the river Derwent above the iron works quay, in which ſpace there being a conſiderable fall at low water, ſuch ſands would be driven out thereby again into the courſe of the Derwent, which will take them beyond the outmoſt heads.

J. SMEATON.

Auſthorpe,
8th *January* 1777.

ESTIMATE for building a new North Pier at the Harbour of Workington.

	£	s.	d.
To the building of 50 rods of the pier on the north ſide, beginning from the pier head, to be of the mean height of 21 feet, 36 feet baſe, and 30 feet top, with a parapet 6 feet baſe, and 9 feet high, at the price of £114 per rod - -	5,700	0	0
To building 38 rods of the pier, to be the ſame inſide as the former, and of conformable dimenſions without, with parapet mean height 5 feet by 4 feet thick, at £79 per rod - - -	3,002	0	0

To

	£	s.	d.
To building 8 Rods of pier conformable at top to the former, and same parapet, at £32 per rod - - - - - -	256	0	0
To digging out the harbour so as to form a clear area next the north pier 85 rods in length and 12 rods width, so as to make 16 feet water at common spring tides, besides what will be used and paid for as fillings between the pier walls including foundations, viz. 40 rods, at £6 per rod - - -	240	0	0
45 do at £12 do - - - - -	540	0	0
Neat estimate - -	£ 9,738	0	0
Add 10 per cent for contingencies - - - -	974	0	0
Total of the exterior pier and clearance - - - -	£ 10,712	0	0

Austhorpe,
8th *January* 1777.

J. SMEATON.

ESTIMATE of interior Works, viz.

	£	s.	d.
To 65 rods of interior wharf wall 7 feet base and 5 feet top and 20 feet high, to be faced with squared stones, at £41 per rod - - -	2665	0	0
To 56 rods of tunnel 5 feet wide, for opening an occasional passage of water from the river Derwent, if found necessary for scouring out the north harbour, at £15 per rod, including extra work about a draw gate for opening or shutting the same at pleasure - - - - -	840	0	0
	£ 3505	0	0
Add 10 per cent for contingencies - - - -	350	0	0
	£ 3855	0	0

Austhorpe,
8th *January* 1777.

J. SMEATON.

Second

Second REPORT of JOHN SMEATON, Engineer, upon the Harbour of Workington.

PURSUANT to the request of Sir James Lowther, Baronet, signified to me the beginning of September last by Martin Dunn, Esquire, I took the opportunity upon the 20th December last to reinspect the harbour of Workington, attended by Mr. James Spedding and Mr. Thompson Ship master of the said place; and the subject of my present view being, as stated to me by Mr. Dunn, to consider by what means the entry into the present harbour might be best facilitated, I accordingly made such observations and enquiries of the gentlemen who attended me, as tended to make me clear in this matter; and also took such measures as appeared necessary for the founding an estimate; from all which I am of opinion that if the frame work were extended in such manner as was agreed upon in London, when the clauses relative to the engineery part of the proposed act were settled; and which was particularly described in the beginning of the clause marked D. that this would be the most likely means of facilitating the entry of the harbour; the description whereof in the said clause is as follows: "And whereas it is apprehended it will be useful for the navigation
" of the said river, that the said frame work of the north side the said river should be ex-
" tended and carried downwards from the north-west end of the said work, one hundred
" yards, according to the present direction thereof, the top of which to be not less than
" one foot higher than the highest spring tide that has been known at Workington. To
" be filled solid to not higher than within four feet of the height of what is solid in the
" present frame work; and that the pile work from the said frame work should be ex-
" tended downwards to where the low perch now stands."

The above extract was the collective sense of the different parties concerned at the time, and which if enacted into a law must have been executed accordingly; but this not having been the case, and being as I now apprehend, called upon to give my opinion what it may be proper for Sir James Lowther of his own free will to execute; I look upon myself at liberty to give my particular opinion, which is, that I do not apprehend it necessary to construct the frame work so high as specified in the above extract, for a very extraordinary tide having happened at Workington in September 1776, that was near upon five feet above the common spring tides; and this frame if to be one foot higher than that must be six feet above the same; it appears to me quite sufficient if the new frame work be raised three feet above ordinary spring tides, which will be so much higher than the top of the upper rail of the present frame work, as this is barely even with the ordinary spring tides;

tides; alſo the pile work propoſed to extend from the termination of the intended extenſion to the low perch, being deſigned ſolely for the keeping the water in its preſent channel; it appears to me that this work may be deferred till the river has ſhewn ſome ſymptoms of its being likely to change it; for as, according to the accounts ſet forth in Mr. Jeſſop's report, it has continued in this channel ſixteen years; and the channel itſelf is now formed in a very compact bed of gravel to a depth from five to ſix feet below the general ſurface of the flat gravel beach to the north, with very gradual ſlopes on the ſides, it does not at preſent appear to me very likely to change its courſe; and unleſs poſitively neceſſary, the pile heads propoſed to be driven may occaſion damage to ſhips if they ſhould happen to ſtick upon them, if they ſhould be driven out of the channel, when otherwiſe they might not touch, or elſe ſtick upon a gravel ſurface much nearer to a level.

It alſo appears to me that the propoſed extenſion of the frame work will add to the ſecurity of the channel's remaining where it is, without the uſe of pile work; and that in caſe the funds will not properly allow the execution of the whole of the propoſed one hundred yards at once, that fifty yards may be firſt done, which will alſo aſcertain the utility that may be expected when the remainder is executed at a future time; for this reaſon, and as the propriety of the execution of almoſt every thing depends upon what it will coſt, I have very carefully conſidered the probable expenſe of extending the frame work per yard ruuning. The top to be three feet higher than the preſent frame work, and the ſolid to be four feet lower than the ſolid of the preſent frame work, which will obviate the objection to the extenſion of the frame work (according to its preſent dimenſions) contained in my firſt report of the 8th January 1777, and ſuppoſing the extenſion to be carried on in a firm and ſubſtantial manner, with Riga or Memmel fir balks of twelve inches ſquare for the main timbers firmly bolted together; and the frames at no more than five feet diſtances middle and middle; this I make to amount to the coſt of £13 4s. per yard running, and therefore for 50 yards £660, and for the 100 yards, to £1320.

This work may be done at a leſs expenſe if done in a ſlighter manner, that is, with timbers of leſs ſcantlings, the frames at greater diſtances, and leſs iron work; but the ſavings that will thence ariſe, I cannot recommend.

Auſthorpe,
3d *March* 1778.

J. SMEATON.

PLYMOUTH YARD.

To the Commiſſioners and principal Officers of His Majeſty's Navy.

The REPORT of John Smeaton, civil Engineer, upon the defective Works in Plymouth Yard.

Honourable Sirs,

CONFORMABLY to the matters ſuggeſted in your letter to the Right Honourable the Lords Commiſſioners of the Admiralty of the 5th April laſt, a copy of which you were pleaſed to put into my hands, and agreeably to your requeſt to me for that purpoſe, I have viewed the defective works in Plymouth Yard, and having been conducted in my view thereof by the officers of the yard, I beg leave to report to your Honors ſuch opinion thereon as by their appearance in their preſent ſtate, aſſiſted by the ſaid officers and artificers, I am enabled to do; and having viewed the whole range of wharfs and frontage works from Mutton Cove at the ſouth part of the yard to and incluſive of the Graving Place, my obſervations were as follows:

1ſt. That the cove, formed at the ſouth part of the yard by a circular pier or wall, is carried up upon a rock foundation to the height of about eight feet with Portland blocks, in front, of a breadth from three feet to three feet ſix inches in bed; and which being flat jointed and ſet in terras mortar, appears to ſtand firm and unmoved. Above the height aforeſaid, the external of the wall both inſide and out are built with limeſtone or marble aſhlers, of above one foot height of courſe or thereabouts; and ſaid to be in bed from fourteen to twenty inches, which were alſo ſet in terras mortar; but on the outſide principally and chiefly, for about four courſes above the Portland blocks, the marble aſhlers are bulged outwards; and that in ſo regular a manner as can only be accounted for by ſome regular cauſe which has taken place at the ſame height, and not from accidental violence or derangement: and though this bulging is moſt conſpicuous in the circular part of the wall above mentioned, yet the ſame kind of appearance extends in a greater or leſs degree from the circular pier above mentioned, through the whole range of wall that fences in the ponds before the maſt houſes; and as the greater length of this range is built upon rock and the other upon a timber foundation; and as that on the timber is in general as free from the derangement of bulging as that built upon rock, I muſt conclude that the bulging

ing of the wall throughout this diſtrict has not been occaſioned by any failure in the foundations.

2dly. On this head I am informed, that the backing, or what may more properly be called the fitting of the wall betwixt the two outſides, (both of which were ſquared ſtones ſet in terras,) was wholly done with rubble maſonry, built with common mortar. Now it appears to me from the whole courſe of my experience, that no compoſition of mortar made with lime burnt from Plymouth marble with common ſand will ever concrete into a hard ſtony ſubſtance if conſtantly under water, or ſubject to be frequently wetted by the return of the tides; or even remain hard after getting ſome degree of induration in firſt ſetting, unleſs it had the opportunity of becoming dry, which never can happen to works thus expoſed to the frequent influx of the tides. The conſequence that naturally follows, is, that the weights that are upon the interior parts of the works reſting upon matter that is ſoft and yielding, its endeavour is to burſt the external coat; the Portland blocks being large, well ſquared, and weighty, have been able to reſiſt the action of the ſemi fluid contents; but the marble aſhler being lighter and leſs in ſize, with a greater number of joints (and which in the uſual way of working, are leſs cloſe behind than before) though they have proved firm enough to prevent the joints from being actually opened; have not been ſufficient to prevent that kind of ſwelling which conſtitutes the bulging of the walls now to be ſeen. Had the backing of theſe walls been performed with the ſame kind of rubble ſtone that was really uſed, laid in a mortar that would grow hard under water, then thoſe derangements could not have happened from the cauſes above-mentioned. If alſo the walls had been backed with brick and common mortar, as the joints would have been comparatively ſmall, and all the matter reduced to horizontal bearings, the action of that infinite ſyſtem of wedges, compoſed by rubble, and laying in every direction, and aided by common mortar, as in its original ſtate like greaſe, to make them ſlide, would have been avoided, as well as the lateral tendency to ſpread thence ariſing.

I took notice of one place in the wall before the maſt pond, where the marble aſhler had not only bulged, but the joints had opened on the backſide next the pond, where it was tolerably fair without, which was generally the caſe; but this was accounted for by a heavy Dutch veſſel driving againſt it. On this occaſion I muſt obſerve, that thoſe walls, having no ſupport by a weight or backing of earth lying againſt them (which together with land tyes, &c. receive the greateſt part of the ſhock) appear to me too ſlight in point of thickneſs (being only about ſix feet at the top) to ſuſtain the ſhocks of veſſels in hard weather; if they had been built for veſſels to lie againſt them. This obſervation will appear confirmed by this remark, that the wharfing fronting the ſlips, which are filled up with

with earth ſolid behind the walls, are in better condition than thoſe behind the maſt pond which ſtand ſingle; though thoſe walls, like a part of thoſe againſt the maſt pond, have been built on timber, the front of which has been deſtroyed by the worms.

3dly. Reſpecting the article of the deſtruction of the foundation timbers by the worm, I muſt remark, that the proper and effectual remedy has already been taken by the officers and artificers of the yard, viz. That of laying a footing of rubble before them, ſo as to engage the mud, warp, and ſullage to cover them, for being ſo covered, all experience ſhews that the worm cannot ſubſiſt to hurt them.

4thly. No part of the works appears to have ſuffered ſo much derangement as the ſouth pier leading into the ſouth channel, though this has been built with Portland blocks from the bottom to the top, it does not want for backing of earth, is of a circular figure, and the Portland blocks have not only like the reſt been walled with terras mortar, but a certain portion of thickneſs of the rubble on the backſide of the wall has been walled in terras alſo. This part is built upon plank and pile, which in like manner as the other has been deſtroyed by the worm, and which in like manner as the other has been underpinned and footed with rubble, ſo that in that reſpect it may be ſaid to be ſecured. The middle part however of the backing of this pier, was like the reſt done with rubble work in common mortar, and which probably aided in a degree by ſome kind of ſettlement from the ſoftneſs of the foundation, as well as from the deſtruction of the timber foundation by the worms, has had ſo great an effect by endeavouring to burſt the outward caſe, which though of Portland blocks it has by ſpreading opened the upright joints in ſeveral places to the extent of two inches, though from the largeneſs of the beds of Portland, it does not appear to have bulged in any conſiderable degree. This work having been underpinned and footed as already mentioned, and many of the joints filled up with thin ſtones in terras mortar by the artificers of the yard, it would appear from theſe joints not opening afreſh, that the work is now come to ſuch a ſettlement and bearing, that being made good as it now ſtands, it may be likely to prove laſting.

6thly. The north pier of the ſouth channel, together with both the entering heads of the graving place, have been all built in a ſimilar manner to that of the ſouth pier of the ſouth channel; they are underpinned and footed with rubble on account of the ſame effects of the worm, and have ſhewn themſelves ſubject to the ſame kind of deficiencies, though not in an equal degree; and which have been alſo in part repaired. There is however one open upright joint in the weſt face of the ſouth head of the graving place that remains open nearly upon three inches; and one of the terminating ſtones of the ſouth altar of the graving place

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place has its joint open to the ſame extent, but this has been apparently deranged by external violence.

7thly. The ſteps in the ſouth channel are greatly deranged below the high water mark, (though very entire above it) notwithſtanding they have been twice repaired by the artificers of the yard ; which ſhews that as the ſteps at the head of the graving place have been very effectually repaired by the ſaid artificers, there is ſomething wrong in the original deſign thereof ; and this appears to me to have been a want of ſolidity of thickneſs in the frontage wall, againſt which the ſteps have abutted ; and a want of cramping the ſteps to the ſaid frontage wall ; beſides all which, the interior part of the ſolid or backing work upon which they ſubſiſt having been built with rubble in common mortar (except that part behind each ſtep that ſupports the tread of the ſtep next above is ſet with brick in terras mortar) and there being in this place an outburſt of ſalt water from the main wall, this waſhes out and paps the common mortar, ſo that the leaſt degree of froſt will rend a work of this kind, however well it might be done with the materials under the circumſtances mentioned.

8thly. The laſt thing viewed was the clerk of the rope yard's office, which as I am informed was built about eighteen years ago. A ſettlement has taken place in the whole except at the north end ; which had it ſettled alſo, the whole front would have ſtood fair. The north end it ſeems was built upon a wall of a reſervoir which is upon a rock ; the reſt is ſuppoſed to have been built upon planking, which having decayed about eight years ago, the above ſettlement took place, amounting to about two inches and a half perpendicular ; and as this ſubſidence is nearly regular, it is moſt naturally accounted for as above. On this head I muſt obſerve, that it is generally accounted the moſt difficult of all foundations, that of being partially upon a rock, and partly upon a ſofter matter, becauſe here being a manifeſt inequality, it is one of the moſt difficult problems in architecture, to form a judgement of what may be ſufficient as an artificial ſtrengthening, to make it equal with that of a rock which can ſuffer no compreſſure. Planking is the common expedient, and where it lies under water and ſo buried in the ground as not to be ſubject to drying, it appears from the works of former ages to be ſufficiently durable ; but where laid in looſe or made ground, ſo as to get a partial dryneſs as may be preſumed in the preſent ſituation) it appears ſubject to the rot in a moderate courſe of years, and therefore to compreſſure. A much better expedient in ſuch a caſe is to pave the foundation and build upon the pavement (laying a courſe of flat ſtones upon it) rather than upon planking. The whole is only a ſmall building ; and it is ſaid not to have ſettled further of late years, the rebuilding of the whole front is no great matter, but it appears to me that the taking it down to the chamber and raiſing that floor may be ſufficient, or even drawing and rectifying the facings, putting on the additional height under the roof may anſwer the end.

9th. Having ſaid as much upon this laſt ſubject as ſeems neceſſary, and as it is a matter of a very different kind from all the reſt, I ſhall now lay it out of the account, and proceed to further obſervations upon the reſt. It appears to me that the general cauſes of all the failures in the works before ſpecified, have been a want of perfection in the art of making mortar, and a knowledge of the proper materials from whence it is beſt to compound it, for works that are either conſtantly under water, or in ſuch a ſituation where they never can become *dry* ; nor can this be properly aſcribed as a fault to any one, as the firſt inveſtigation of this buſineſs was brought forth by neceſſity thirty years ago, in the building of the Edyſtone lighthouſe, and though the ſame compoſitions and methods have been applied and improved in my ſubſequent works ever ſince, and conſequently known not only to the reſpective artificers employed, but always freely communicated by me to all ſuch as deſired the knowledge thereof, yet not having been publiſhed, I find even at this day they are very far from being generally known.

10thly. As I have already intimated, I lay it down as a fundamental poſition, that no compoſition can be made with lime burnt from Plymouth marble, nor any limeſtone of the nature thereof, or of common white chalk mixed with ſand, which compoſes the common mortar, that will ever acquire a ſtony hardneſs under water, or where it can be perpetually ſupplied with moiſture from the daily flow of the tides. But lime from the ſame kind of ſtone or chalk when reduced to a dry powder (as uſual by quenching) and mixed with half its quantity (by meaſure) of Dutch terras ; and well beaten together for many days ſucceſſively, without ſand, will acquire a ſtony hardneſs under water, after it is firſt ſet in building, which it generally ſpeedily does. This compoſition, commonly called terras mortar, has been in uſe time immemorial, and if well performed and diligently applied, very ſound and good work has been performed therewith, but even this mortar will never acquire the hardneſs of good Portland ſtone, which I have by trials and experiments been able to attain : but though this lime uſed for terras mortar is generally of the cheapeſt kind, yet the terras is ſo dear a material, having been for many years from three to four ſhillings per buſhel in the light dry powder, and the quantity of mortar made therefrom is ſo ſmall, and that with ſo great an expenſe in the labour of beating it (in general nearly half the value of the material) that it has in general been very ſparingly uſed : in terras brick-work, one brick in breadth on the outſide is generally deemed ſufficient, very rarely more than a brick length ; and in aiſler work, ſometimes four inches and a half of the joint within the face, ſometimes nine inches, and at moſt as in the works of his Majeſty's dock yards, the whole aiſler or Portland blocks are ſet in terras mortar.

11thly. This dearneſs of the material, and conceiving the above as ſufficient to defend the inſide works from the immediate action of the water, has induced the backing as it has been called, to be generally performed with common mortar: but brick has for this purpoſe been generally preferred to rubble or rough ſtone, becauſe the thickneſs of the mortar joints will be leſs, and the ſurfaces lying level one upon another, they ſupport one another like pillars, with very little tendency to ſpread; and this kind of work when built within dams, which often for months together give time to the mortar to acquire a degree of hardneſs and conſiſtency, as is the caſe in building the King's docks; I ſay this kind of work ſeldom ſhews any deficiency. But in the wharf walls which are generally done by tide work, where the water flows over the whole every tide, the common mortar work never acquires any competent hardneſs, but when covered up by the heaping on of freſh materials of the ſame kind, though thereby defended from the immediate action of the water, it has never in any length of time where I have had the opportunity of ſeeing old works taken to pieces, acquired more than the conſiſtence of compreſſed *curd*, which with freſh beating will become mortar again fit for the trowel. This kind of work therefore (tides work) coming to the moſt ſevere trial of any, we muſt not wonder, if while it is taking time for compreſſure, it ſhews ſymptoms of internal weakneſs: the want of certainty therefore of anſwering its end, with credit to the artiſt and artificer, has led me further to ſtudy how to get a compoſition of mortar for ſuch kind of works, that will internally as well as externally acquire the hardneſs of ſtone, and that without greatly exceeding the price of maſonry in common mortar.

12thly. The inveſtigation of a compoſition for the Edyſtone has in its iſſue led me to this point. To recount the ſteps taken, would be tedious as well as not to my preſent purpoſe; ſuffice it to ſay, that as all the work there was cloſe jointed, the *expenſe* of terras mortar was no object; but the length of time it required to beat it to the beſt conſiſtence, was likely to prove a very material impediment. This induced me to make trial of lime burnt from every ſpecies of lime ſtone I could then hear of or procure, and I found that as much depended upon the quality of the ſtone from whence the lime was burnt, as upon the indurating ingredient; and that the deſired effect was produced by the uſe of a lime from *Aberthaw* in Glamorganſhire; but the lime actually uſed, was of exactly the ſame nature, and came from Watchett in Somerſetſhire, on the oppoſite ſide of the Britiſh Channel, where the ſame ſtratum runs, and is in both places called *Blue Lyas*.

13thly. In theſe original experiments, I had the ſatisfaction to find not only that terras mortar made up with this kind of lime, in lieu of the common ſort, greatly exceeded

exceeded in hardneſs common terras mortar, but needed no more beating than common mortar *ought* to have; and alſo, that this kind of lime beaten up with common ſand, (*without terras*) was almoſt as ſtrong as the common terras mortar could be rendered by any degree of beating, and ſuperior to it, if the latter was but indifferently beaten; and that ſalt water to this kind of lime for under water work, was as good, if not better than freſh, which was a circumſtance very material to my views at that time.

14thly. It was not till ſome time after this building was erected, that I found this ſpecies of lime ſtone was not confined to the neighbourhood of the two places mentioned, but it was a freſh diſcovery of the moſt agreeable kind to find it in ſeveral and very diſtant parts of this kingdom. This put it in my power to try further experiments, and to uſe it in works where a much greater degree of œconomy was required, than in the mortar of the Edyſtone, and from various trials I found that two meaſures of this kind of lime to one of terras, or Pozzelana from Italy, beaten up with three meaſures of ſand, coarſe and fine mixed, made a compoſition of equal goodneſs with that of the Edyſtone mortar, but doubled the quantity, or that could be made with the ſame quantity of terras, in the common mixture; and that eight meaſures of this lime to one of terras or (Pozzelana) and fixteen meaſures of ſand (fine and coarſe) made a mortar for backing very nearly equal to the common terras mortar; and as the greateſt part of the bulk of this compoſition is common ſand, its price per hod in moſt ſituations will not much exceed one-fourth of that of common terras, nor much more than double the price of common mortar. In many places where ſtone naturally riſes in flat beds, as the blue lyas itſelf does (and is uſed for building-ſtone in the countries where it is found) as alſo the Purbeck aiſler, &c. and the ell and edge ſtone, brought as flat paving from Yorkſhire, all of which being uſed as backing, where from ſituation it can be procured at a moderate price, this greatly leſſening the quantity and vacuity of joints even compared with grey ſtock brick work, and thereby leſſening the quantity of mortar in a rod of work, thereby reduces the expenſe of mortar to be no greater than that of the common ſort, and at the ſame time making a ſtronger bond throughout, produces firmer maſonry; but in all caſes as the bond made in converting the *whole* into one *maſs of ſtone*, takes away the neceſſity of uſing ſuch maſſive ſtones for the front (which is generally the moſt coſtly part of the work) it follows, that in all caſes of water buildings, by the uſe of proper water lime, inſtead of the common ſort, they may be done at an equal, and in many caſes at a leſs expenſe, as well as a much greater degree of ſolidity and certainty, than by the common conſtructions, with the common materials.

15thly. I call

15thly. I call the lime for these purposes by the general name of *water lime*; for after I found its properties not confined to the blue lyas stone, but even residing in a certain species of chalk which is to be met with near Petersfield in Hampshire, as pointed out in the said Committee of engineers' report, and which at Portsmouth is commonly known by the name of grey lime; but I had also found it near Lewes in Suffex, and there called clunch lime, as also at Guildford and Dorking in Surrey; but what is of most consequence to the present business, as I am informed by scientific friends whom I can depend upon, that the true blue lyas is in quantity at Lyme in Dorsetshire, and I have myself observed it not very far from thence at Axminster in this county.

16thly. I am sensible I might have spared myself the greatest part of this disquisition, but as I humbly conceive it may tend to lead your Honours into the true nature of this business, it will in effect tend to shorten what I should otherwise have to observe upon particulars; to return therefore to my immediate subject.

17thly. As from information I do not find that the defective works (the stairs excepted) have lately given way, I would suppose they have settled till the parts are come into contact; and therefore may probably remain so for many years, before they need rebuilding, as before noticed; and as the effect of the worm has been remedied in the most judicious way of which, as far as I know, the subject is capable; I do not see that any thing can be done more effectual, than carefully to point and make good the joints wherever they are found defective, with the best composition above mentioned, and when the upright joints will admit thereof, to cut Purbeck flat paving stones, a very small matter wedgewise; and drive them in with a soft wooden maul, and before closure with the last pierce, to cram in as much mortar as possible, of the same kind mixed with pebbles, where the joints will take them, with the end of a board or battan; the mortar being rendered a little more fluid, by a small addition of water. This will not indeed take away the *appearance* of the bulging courses, but for this I see no remedy but to take down the walls to the top of the Portland blocks, and then if the rubble contents in common mortar are taken out, and the whole built in with the different kind of mortar specified (though of the same stones) I shall not be apprehensive of any further bulging or settlement, except it should arise from the foundation; and of that where there is nothing but soft matter, into which the piles can be driven, I do not look upon in the nature of the thing there can be any absolute certainty.

18thly. Respecting the steps in the south channel, I would advise their being taken down till there appears something solid to build upon, and to wall the inside core or backing with

with the composition given, called Portsmouth terras, made with the water lime from the lyas stratum at *Lyme*: to build the front wall with a string course of at least eighteen inches thick, cutting the outward stones into steps out of the solid; and cramping every other step to the front wall, which would be still more satisfactory if these front stones of the string course were formed from blocks of moor stones cut into three or four steps each: the steps themselves to be carefully bedded in the best composition, and carefully pointed, so as entirely to exclude the water; and proper conduits to be carried through the work, to take off the outbursts of salt water from the main wall: the work will become still more solid, if there be no occasion to continue the steps so low, as suggested by the officers.

19thly. It now only remains that I advert to the question contained in your letter of the 5th April, before referred to:—that is, "whether rough masonry at the back of "the aislers would not (on account of the irregular figure of the latter on the outside) "if carefully performed, answer as well as brick, which being of a regular form "cannot be so well worked into the back of the aislers, nor bonded with the rough "masonry in the interior parts of the work, in which case the whole would not be so "well connected together?"

From what I have already said, your Honours will perceive, that the resolution of the question depends upon that of another; with what sort of cement is the work to be performed? If it is to be with the best composition of water lime, as I have mentioned, it will together constitute one solid stone, and then it will be of little consequence what may be the relative figure of the parts: and that this will be the case in a certain degree, if done with well-beaten terras mortar, your own observations have proved; for on examination of the back side of walls so built (being those on the south side of the graving place, and at the north side of the south channel) though you found them "not done with square masonry as the contract directed," yet the rubble masonry in terras wherewith they were done "appeared *very sound and firm.*"

20thly. The rough masonry in terras has been reported by the master bricklayer to be more expensive to the contractor, than if done with square masonry in terras, and this is confirmed by my own calculation, and will readily appear to your Honours when it is adverted to, that in rubble masonry there is at an average nearly double the quantity of vacuity that there is in square masonry, even if but rudely squared, and which must be filled with the most costly of all building materials, videlicet, terras mortar. Yet I cannot agree with the master bricklayer in supposing it *better*, because as the getting of

of mortar of any kind perfectly well beaten, may be eſteemed the moſt difficult part of the whole; I ſhould always prefer that conſtruction which at the ſame expenſe had the moſt ſtone in it, and the leaſt quantity of vacuity to be filled with mortar of any kind.

21ſt. If the queſtion regarded dry work, as common mortar of common lime and ſand will, if well beaten and proportioned, come by length of time to the hardneſs of ſtone, then I ſhould judge the rubble work ſo performed to be equal to brick; becauſe it would then be in the ſame predicament as water work performed with proper water cement. But if the work is ſuppoſed to be under water, as the common mortar as already obſerved will never come to a ſtony hardneſs, I judge that kind of rubble work to be greatly inferior to brick for backing, as preſſure will make it tend to ſpread, which it has been obſerved from their figure is not equally the caſe with brick. Beſides, as brick is a more dry and abſorbent body than marble and moſt kind of ſtones, it drinks up the moiſture, and cauſes the mortar to ſet more ſpeedily, and by that means often gives a greater opportunity of its acquiring ſome degree of firmneſs before the water comes upon it, which in this caſe is a conſiderable advantage. I therefore cannot recommend rubble backing in works under water, where better materials can be had, and more eſpecially in tide works, where there is the leaſt opportunity of the mortar's ſetting by the drying quality of the air.

J. SMEATON.

BRIDLINGTON PIERS.

The REPORT of John Smeaton, Engineer, upon the ſtate of the Bridlington Piers, with the moſt probable means of preſerving the ſame from the deſtruction of the worm.

THIS Harbour for ſhipping, formed artificially by the piers at Bridlington quay, being at the bottom of the great bay conſtituted by the great projecting point of Flamborough Head, with the coaſt tending from thence ſoutherly, is not only ſituated commodiouſly for the reception of the coaſting traders, when they cannot make the Humber to the ſouth, or Whitby on the north, but the piers are ſo diſpoſed as to afford all poſſible ſhelter for veſſels within them. A harbour therefore ſo ſituated, and ſo conſtructed, being found to be of great utility, its piers have been erected and upheld at a great expenſe, but they have at firſt been built with timber probably with a view to the ſaving in the charge that would have accrued by conſtructing them with ſtone, it has unfortunately happened, not only that theſe piers are ſubject to the gradual decay that neceſſarily muſt attend all works of wood, when expoſed to the action of the ſea, but alſo to a particular kind of decay ariſing from the continual eating of a certain ſpecies of worm, that infects the timber work of this harbour, greatly differing from the common worm whereby ſhips are deſtroyed, and which is ſaid to have been originally brought from the Weſt Indies.

The object of my view of theſe piers made at the deſire of the Commiſſioners for the preſervation thereof, the 29th, 30th, and 31ſt of December laſt, was not with any intent of improvement of the diſpoſition of the piers and works, but altogether to conſider and give my opinion upon the beſt method to be taken in future repairs, and for the preſervation of what is now ſtanding.

I have now very ſeriouſly conſidered theſe propoſitions, and however difficult it might at firſt ſeem, I now hope to be able to lay down a very practicable method whereby a great deal of expenſe ariſing from the decay of the worm may be avoided; but that what I have to offer may be clearly underſtood, I beg leave to ſtate what was pointed out to me by the pier maſter, and which appeared to me upon inſpection to be the caſe reſpecting the nature of this worm, and its operation.

This

This worm appears as a ſmall white ſoft ſubſtance, much like a ſmall maggot, ſo ſmall as not to be ſeen diſtinctly without a magnifying glaſs, and even then a diſtinction of parts is not eaſily made out; it does not attempt to make its way through the wood longitudinally, or along with the grain, as is the caſe with the common ſhips' worm, but directly, or rather a little obliquely inward; the holes made by each worm are ſmall proportioned to the ſize of the worm, but as they are ſo many in number as to be but barely clear of each other, as they do not appear to make their way by means of any hard tools or inſtruments, but rather by ſome ſpecies of a diſſolvent liquor, furniſhed by the juices of the animal itſelf; it follows that as the animals which overſpread the whole ſurface of the timber expoſed to their action, proceed progreſſively forwards into the body of the wood, the outward cruſt becomes macerated and rotten, and gradually waſhes away by the beating of the ſea, ſo that in fact the timbers, planks, &c. gradually waſte in ſize and thickneſs, till at laſt becoming too weak to ſupport the ſtrain upon them, they are obliged to be replaced and new done many years ſooner than would happen by the natural decay of timber in ſuch circumſtances, if unaffected by the worm.

The worm is found lodged in a cruſt of wood, generally from a quarter to half an inch deep, that part of the wood under this cruſt remaining perfectly ſound. The rate of progreſſion, as I am told, is, that a three inch oak plank will be deſtroyed in eight years by action from the outſide only.

It is furthermore obſerved, that thoſe animals do not live except where they have the action of the water almoſt every tide, for they are not found in the timbers above the level of common neap tides, high water, or indeed ſcarcely ſo high; ſo that it is to be inferred, that if any happen to fix ſo high as the common neap tide mark, if a few low tides fall out together with ſtill water, as frequently happens in ſummer, the worm thus unwaſhed dies, and a ſtop is put to its further progreſs higher.

Again, it is very obvious that ſo high up as the piles and work are covered with ſand, or as ſoil lies againſt it, the wood is perfectly free from the worm, ſo that the parts affected are what are alſo expoſed to the air, that is from the ſurface of the ground or ſand to high water neap tides. Whether a deprivation of the action of the ſea water, accompanied by a continual change every tide, or a deprivation of the benefit of the free circulating air each tide, occaſions the loſs of what is neceſſary to their ſubſiſtence, may be a queſtion, but which indeed it does not ſeem neceſſary now to reſolve; this however is the fact; for on the inſide of the planking againſt which the ballaſt, ſand, or gravelly matter which is heaped by way of filling and giving ſolidity to the piers' baſe, and which in general is filled above the high water neap tides, is alſo found to be a preſervation to the inſide

inſide of the planking, though from the outſide only they will waſte, as has been ſaid, three inches in eight years.

The rebuilding thoſe piers with ſtone would doubtleſs be an abſolute cure of the evil complained of; and if they had fortunately been done ſo at the firſt it would have been well: but as it appears to me that it would be impracticable now to conſtruct thoſe piers of ſtone, without a much larger fund than there is any likelihood of being raiſed for the purpoſe, it remains only to make the beſt of them as they now ſtand; I ſay impracticable without a much larger fund, becauſe if attempted to be proceeded with gradually with ſtone upon the preſent funds, the progreſs would be ſo ſlow, that a great part of the preſent piers would be down, and the harbour lie open, before it would come in turn to replace them with ſtone, ſo that the repairs of the timber work muſt ſtill go on, and if it exhauſts the preſent funds to keep the preſent works in repair, a double outlay would in conſequence be incurred to which the preſent funds would be inadequate; and though the timber repairs would gradually leſſen as the ſtone advanced; yet it would be ſeveral years before the outlay on the current repairs of the timber piers would become a very material and ſenſible eaſement; for theſe reaſons, deſpairing of ſeeing any thing very extenſive done here with ſtone, I have very ſeriouſly applied my mind to the propoſitions laid before me, which in ſubſtance are, however, to make the beſt of what now is.

It will alſo be neceſſary, for the clear apprehenſion of what I have to deliver, that it be underſtood how the outſide of the timber work of the piers, that is, what is ſubject to the worm, is formed. It is obſervable that the outſide of the piers is formed by a ſtrong row of ſquared piles of oak, in general about a foot ſquare, and near the pier heads the ſpaces between them not much more than the breadth of the piles. Inſide of thoſe they are planked with three-inch plank, in the general old ſhip plank, but of late years there being a ſcarcity of this, fir plank has been in ſome places tried, which is found ſtill more ſubject to the worm than oak; this planking is to keep in the ballaſt, wherewith, as already mentioned, the piers are filled; and which preſerves the inſide of the plank from the worms, while the outſide being expoſed to the free action of the ſea, is ſubject to their incroachments in the manner that has been mentioned, and not only the ſpaces between the piles, but alſo behind them; becauſe as there is ſeldom a water-tight joint between the plank and the back ſide of the piles, the ſea drives in, and nouriſhes the worms; as alſo in the joints between plank and plank, and thereby widens them, ſo as in time to let the ſand and ſmall parts of the ballaſt waſh out through them, which on this accoun needs repleniſhing from time to time: it is alſo obvious that the piles themſelves will be expoſed to the worm on all ſides, for by the ſame rule that the worm gets into the plank behind them, they will affect the back ſide of the piles, the other three ſides being open to them.

It

It is doubtlefs on account of the fpeedy decay and confequent weakening of the piles, in the very part of them where the main ftrain lies, that it becomes neceffary to plant the piles fo near together, and hereby a much greater expenfe is incurred than would be neceffary if they were fubject to no other decay than what length of time would produce, that is in cafe there were no fuch worm, or what would amount to the fame thing, in cafe the worm could be effectually fhut out.

This latter, viz. the fhutting out the worm, appears to me very practicable, the method whereof for new outfide work I will now defcribe. Suppofe the piles driven and lined with planking in the ufual way, only a little more pains taken than heretofore in fquaring the fides of the piles that look one towards another; when the work therefore is completed, I would begin by amending the fquaring the fides of the piles, fo as to reduce them to ftraight-fided figures; then I would adapt chocks of fir to thefe fpaces between pile and pile to be driven lengthways, and which being feparately fitted and driven in may be very nearly adapted to the place that each is to occupy; and between every layer there is to be a bed of tar and oakum, or tar and hair, which is to be crammed into every little vacancy that appears after the driving in of each chock, and fo to go on ftratum fuper ftratum between every vacancy between pile and pile, till you come juft above the height where by experience you find the worm to ceafe; in fhort you may then confider all the fpaces between pile and pile completely walled up with fhort blocks of fir, bedded in tar and oakum, and all the vacuities completely filled with the fame fubftance. This done, the chocks being left a little fwelling before the face of the piles, the whole is to be dubbed off with an adze to one general furface, upon which a fheathing is to be put on in the manner of the fheathing of fhips, the whole furface of which to be filled with fheathing nails, which, affected by the falt water, will throw a coat of iron ruft over the whole furface, and preferve the work from the worm, in the fame manner as in the fheathing of fhips. It is not improbable that this cruft of iron may be wholly impervious to the worm for many years; but fuppofe that in the compafs of ten or twelve years it fhould be found that the worm had got through the fheathing, new fheathing may then be put on at a very light expenfe, and the work guarded for as many years more, and fo on as long as the main timbers will laft from the abfolute decay of time.

In the execution of this method I would obferve, that I would begin the loweft tier, layer, or ftratum of chocks, as low as I could well get for water, or as low as there is any probability of the fand or foil being taken away, and continue them up to where the worm ceafes, and thereby putting in kant pieces, the fheathing will be reconciled with the back planking, and fo continue from thence to the top of the pier.

Again,

Again, I have mentioned that the fides of the piles ought for the fake of the more regular fitting in the chocks to be a little better fquared than common, yet I do not mean by this that the timber ought to be wafted or weakened by being hewn dye fquare; it is fufficient to bring the prominent places to a fquare, leaving the wainy parts to be brought nearer by being notched in with a chiffel after the main work is fixed ready for the chocks; for as I fuppofe every chock particularly adapted, it is no matter that they fhould be all exactly of a length, or their ends be a perfect fquare; and I would alfo further remark, that if the chocks are made out of ftuff about fix inches fquare, fo as to take two breadths in the thicknefs of the piles, they may be both made much more readily, and more completely fitted than if attempted to be put in from whole balks. I would alfo add, that in cafe in time the foil fhould happen to wafh below the ground tier of chocks, fo as to leave the under work expofed to the worm, on fuch accident it will be better to drive a row of ground piles about fix feet from the pier, and fill the intermediate fpace with chalk ftones, &c. fo as to retain foil againft the chock work, than attempt to put in chocks under the former, to which in fuch circumftance it may be difficult to make a good joint.

This kind of work will doubtlefs require a little care and attention, but will be fubject to no real difficulty or hazard, nor be attended with any confiderable expenfe; and indeed were this expenditure altogether additional, the quantum would be no ways proportionable to the duration it will communicate to the work; for if it be confidered how much folidity this method will give and the whole being preferved of its original ftrength, there will be no need of allowance for wafting on account of the worm, fo that it will rather appear in the light of a faving; for I am fully of opinion that if the piles are put at two feet fpaces, where they are now put at one, or at three feet fpaces where they are now put at two, they will in reality be in proportion more ftrong and valid than at prefent; and that the faving of fo much prime and valuable oak timber will nearly pay all the other expenfes.

I come now to lay down what is to be performed to preferve the work already done, and not as yet fo far decayed as to require new; and I fuppofe the fides of the piles not having been driven with any view to this kind of treatment, will be found to be irregular and require too much cutting to bring them to plain furfaces every where, but in many places this may be done, and indeed every where a chock may be fixed in front by going in bevil, and fixing by a couple of fpikes; by this means at leaft the front may be made good; and as the decay of the outface of the planking may be attended with fuch irregularities as cannot be fitted with chocks, I would recommend thefe fpaces between the front chocks and back planks to be made up courfe by courfe with brick and terras mortar, which will grow hard in the water, and enable the whole of thefe irregular cavities to be filled completely full of matter, fo that the worm will be thereby as effectually killed, and a frefh

a fresh growth prevented as in the new work. The faces of these chocks being then neatly dubbed off along with the faces of the piles, and a sheathing put on as before directed, I have not the least doubt but that such parts of the work as, though considerably decayed, still remains strong enough to resist the violence of the sea, will be preserved for a considerable term of years, that otherwise would be in a few years in a state of ruin.

Besides the above described works that compose the outside of the body of the piers, there are, at certain intervals, still larger detached piles driven as fender piles, which are equally eaten away by the worms as the others; to those I would only advise that their whole surface on every side be driven or filled with sheathing nails from a little below ground to neap tide mark as before recommended.

As it appeared to me the whole of the north pier head lies dry to the ground at spring tides in moderate weather, but if it should happen that any part cannot be easily come at to fix the low tier of chocks within the ground, I would begin by laying a tier of the large block stones close against the foot of the piles, and in some degree adapted thereto, kanting off the outward angle, and fixing each stone by two strong dogs or iron cramps one near each end of the block, the dogs to be firmly fixed at one end to the piles or timber works, and the other leaded into the upper surface of the stone, then ramming full every cavity between the blocks and the timber work with bricks and terras mortar, the chocks may be founded on this, a little below the upper surface of the stone blocks.

A further requisition from me, was, in what manner the block stones already provided may be most effectually applied?

As I have already shewn how the worm may be prevented, and even stopped where it has already entered, without much use from stone work, it will follow that much the greater quantity, said in the whole to amount to 750 tons, will remain on hand.

I observe that the cliffs to the eastward of the north pier are greatly wasted by the continual beating of the sea, and in a way of wasting still more; so that in process of time, it may be justly apprehended, that unless something be done to controul it, the sea will make its way into the harbour; and indeed had it not been for a great number of the block stones that have been promiscuously tumbled down into the external angle, between the north end of the north pier and the main land, that has prevented its direct progress that way, it is not unlikely but that this would have already happened, a circumstance that would be fatal to the harbour, as the case would be very different here from what it is from the want of junction from the west end of the south pier with the main land, as the sea only comes through the beach by recoil, after having in a great measure spent its fury upon the beach; whereas here, it would come in by the most direct passage into the very place where the principal ships lie.

It

It appears therefore to me that those stones being already upon the place, cannot be better disposed of than by securing this neck of land, in lieu of using a quantity of timber work in this place also, that otherwise might be necessary. The most easy and simple way of constructing such a bulwark, and what seems to me best calculated for receiving and diverting the shocks of the sea, is for the face of the bulwark to be disposed in a circular form, and the ground course let down its whole thickness, or thereupon into the solid clay. I do not mean that there should be any work upon the blocks, except what is done to bring them to a steady bearing in place; and except what may be necessary for the stairs in case a stair is thought indispensable, and which I would otherwise advise to be avoided, to shun the making any break into the regular face of the works.

As the surface of the clay bottom appears to be in a state of wear by the action of the sea though seemingly slow, yet it may be expected that in process of time it will so wash away as to expose the matter upon which the ground course is founded to the action of the sea, and therefore it would be the regular course of business to found the ground tier of blocks upon a sheet of plank piling; but if it is considered that this sheet of plank piling is equally liable to be laid bare, and when so, must for the same reason as the piers, be defended by something else; and as it is probable that it will be several years before such defence will become necessary; and when necessary may be defended by letting down another row of blocks at the foot of the former; it seems to me, that the original expense of pile work may for the present be dispensed with; and as besides doing the work specified a considerable quantity of the block will still remain, they may not only be applied to the occasional purposes before mentioned, but also in making good the insertion of the bulwark into the main land, as the cliffs gradually wear away.

I do not mean that any mortar or cement should be used in the construction of this bulwark; but to prevent the gravelly matter from washing through the joints of the blocks, I would advise a stratum of heather to be laid upon the chalk stone fittings; and also the joints of the back sides of the blocks to be well crammed up with the same; or in lieu thereof hay may be used for the same purpose.

J. SMEATON.

Austhorpe,
15th *May* 1778.

SUNDERLAND PIER.

The REPORT of JOHN SMEATON, Engineer, upon Mr. SHOUT's plan for rebuilding and extending the old pier of the Harbour of Sunderland.

HAVING carefully viewed the harbour and piers of Sunderland, and received the information of ſeveral eminent maſters of ſhips belonging to that port, having alſo conſidered the plan produced to me by Mr. Shout their Engineer for the improvement of the ſaid harbour, I am of opinion, as follows :

1ſt. That nothing appears to me ſo likely to improve the depth of water over the bar (which is unanimouſly repreſented as the moſt deſirable circumſtance wanting towards its improvement) as the prolongation of the old pier to the low water mark at the leaſt; and as the direction of the laſt ſtretch of the old pier has been now proved by many years experience to afford a ſufficiency of ſhelter to the ſhipping from out winds and ſeas, and alſo to be in a commodious direction for going in and out; I am of opinion, that what has been ſhewn by experience to be right, ought not to be eſſentially altered; that is, that the head of the advanced pier ſhould be in the line of direction as the preſent pier.

2dly. That as a conſiderable part of the old pier from the head inward appears ſhaken, and its foundation ſapped, I ſee no more eaſy or proper mode of repair, than that of re-erecting it on a new foundation; and as by doing this, according to the plan exhibited by Mr. Shout, a projecting part of the pier will be taken off, that now appears to diſturb the current of the river, and break its force in time of great land floods, which are the principal agents towards ſcouring the channel and keeping down the bar; the current of the river will thereby have a more direct courſe to ſea; and being preſerved in one direction by the pier from ſpreading, will not only make a deeper channel alongſide of the pier, but, acting more directly and immediately upon the bar, deepen the channel over it in like proportion.

3dly. I therefore approve of the plan of Mr. Shout, but look upon it that it will be an improvement to the ſafety and ſhelter of veſſels within the head, that inſtead of carrying it out in a direction parallel to the terminating direction of the old pier, gradually to bring the new pier round, ſo that its terminating head may be in the ſame individual place as if the old pier were extended to the ſame point.

4thly. As

4thly. As the new pier is carrying out, the effect of it will be ſeen, and the degree to which it ought to be extended more certainly judged of; but I am of opinion it cannot be too far extended, even beyond the bar, if circumſtances of time and expenſe will admit.

5thly. I apprehend it will be proper to begin the extenſion of the pier from ſomewhere near upon abreaſt of the preſent old pier head, and to carry it on to ſome length, ſuppoſe about two years work, before any of the old pier is removed; then to work backward removing the old pier, as the new one advances towards the point of junction, by which means the ſhelter to the harbour will be preſerved.

6thly. As I am of opinion, that as the extenſion is carried on, the north ſand will follow it nearly at the ſame diſtance as at preſent, whereon the ſeas in like manner breaking and ſpending themſelves, will keep the harbour in the ſame degree of quietude, with the advantages mentioned of a deeper channel over the bar.

J. SMEATON.

Gateſhead,
16th *January* 1780.

N. B. The old pier as it is removed muſt be as entirely eradicated as poſſible, that nothing of wood or ſtones may be left to prevent the land floods from deepening the channel in the ground upon which the old pier now ſtands.

TINMOUTH HARBOUR.

REPORT on Tinmouth Harbour's Mouth.

June 21ſt, 1769.

HAVING this day viewed the harbour of Tinmouth, and particularly that part of the entry thereof lying between the Low Lights and the Black Middens, I am of opinion, that it will be a great addition to the ſecurity of veſſels entering and going out of the ſaid harbour, if the looſe ſtones that are ſcattered upon the north ſhore, between the Muſcle Scalp and the Prior Stones, were removed. Theſe ſtones in ſome places extend themſelves into the channel, ſo that ſhips that happen by accident to take the ground, often receive damage that would be prevented by their removal, and alſo by affording a greater width and capacity, would greatly add to the conveniency of veſſels working to windward either into or out of the harbour.

The rocks called the Prior Stones, I am of opinion for the ſame reaſon ſhould be removed and made level, together with ſuch others as obſtruct the channel as far as they can be got at.

The ſtones that lie near the Black Middens may be ſtowed away in the hollows of the ledge of rocks, ſo as to ſtrengthen and increaſe the utility thereof as a break-water, and which if carefully depoſited in the method of a pile of cannon ſhot, I am of opinion will lie where they ſhall be placed. Thoſe at a greater diſtance may be laid in the ſame method on a ridge extending over the higheſt part of the ground between the Black Middens and the ſhore, which will alſo add to the break-water, and in ſome meaſure prevent the current from dividing near high water into two channels; and as to thoſe ſtones that lie up nearer the Muſcle Scalp, they may be depoſited under the high cliffs, and will tend to the defence and ſecurity thereof.

Thoſe ſtones may be removed in different ways, each of which according to circumſtances may have its advantages; and indeed I would adviſe them all to be tried, from whence it may be with certainty determined, which is executable at the leaſt charge.

1ſt. The ſmaller kind of ſtones may be moved by hand-barrows.

2dly. The larger kind may be ſplit with gunpowder and mauls, and then removed by hand-barrows.

3dly. They

3dly. They may in ſome places both large and ſmall be removed by Carts.

4thly. They may be removed by lighters laid on ſhore, and loaded at low water, and removed on tide of flood.

5thly. They may be drawn over the rough ground by windlaſſes and tackles, to be moved from place to place, as need ſhall require.

The ſtones may be laid hold of by eye-bolts, fixed in holes bored by a jumper, or they may be harneſſed with chains.

I would adviſe that the workmen at all times employ themſelves upon thoſe ſtones that lie loweſt and neareſt the channel, and as the flow of the tides obliges them to retreat, to work upon thoſe that lie higher.

I obſerve that a great many ſtones to be removed are very good lime ſtones, which, if broken up, I apprehend many would be glad to remove for the ſake of the lime.

J. SMEATON.

P. S. In coming down by way of South Shields, I obſerved a place called the Mill Dam, which, if the trade requires it, may be very properly converted into a wet dock, that would hold a great number of ſhips.

SCARBROUGH PIER.

To the Commiſſioners of Scarbrough Pier.

GENTLEMEN,

I WAS duly favoured with your order of the 15th of May laſt, from the hands of Mr. M'George, referring to a caſe to be ſtated by Mr. Gilbert, for my opinion thereon, and alſo reſpecting the carrying on the works of the pier in future, which caſe was alſo incloſed, deſcribing the method by which the works were propoſed to be carried on. All which having carefully conſidered, and having referred to my former plans and eſtimates, I find, that in the courſe of twenty-five years, there have been executed from my deſigns and directions upon principles ſimilar to the mode of operation deſcribed in the caſe incloſed piers for the following harbours, videlicet,

Aberdeen, Aymouth, Portpatrick, in Scotland; and St. Ives in Cornwall: all of which have anſwered and given entire ſatisfaction. The outſide ſtones of any of the above were not above three tons weight, nor were they backed with any thing but promiſcuous fittings, from a ton to about a cube foot in a ſtone; the general weight of the fitting ſtones were about half a ton in a piece. It is however to be obſerved, that the whole were quarry ſtones, rough and angular, and not rounded by the action of the ſea. We uſed no gravel for wrecking the work, but in what was above low water, the interſtices were filled by hand, after ſet with ſmall ſharp rubble ſtones of the ſame kind; and it is to be further noted, that the outſide blocks, after being roughly ſquared, were not laid upon their beds, but ſet with their angles upwards, ſo that every ſtone was jambed between two, ſet in a ſimilar manner below. I am therefore of opinion that the method propoſed will be ſufficient to reſiſt the violence of the ſea, when got up to its full height, and covered with an entire platform of large blocks upon the top.

In regard to the economy that may attend this mode of operation, I muſt obſerve, that in all the piers above mentioned the whole or by far the greateſt part of all the ſtones employed were not found by the ſea ſhore, but by neceſſity brought from quarries by land carriage, ſo that the expenſe upon the whole was not leſs than four ſhillings per ton; and would have been far greater, had nothing but large blocks been employed. It may therefore in ſome ſituations be better economy to make uſe of the ſtones that are there, if large, though rounding, and to fill all ſolid, than either to break them to render them angular, or fetch this kind of ſtones from quarries within land. It ſeems therefore probable that ſomething may be done by way of eaſing the expenſe, and increaſing the expedition; but the proper mode of operation depending altogether upon local circumſtances, I am unable to form my opinion fully thereon without a view of the premiſes.

I am with great reſpect,

Gentlemen,

Your moſt obedient humble ſervant,

J. SMEATON.

Auſthorpe,
9th *Auguſt* 1781.

ESTIMATE for improving and enlarging the Harbour of Scarborough, in the County of York.

	£	s.	d.
To extending the preſent pier 150 feet, containing 115 ton per foot running, at 6s. per ton - - - - -	5,175	0	0
To building a new inner pier, containing 320 feet in length, and 31 ton per foot running, 6s. - - - - -	2,976	0	0
To making a wharfing to confine the ſands, extending 1,300 feet, at £2. per foot running - - - - -	2,600	0	0
To clearing the preſent area of ſand, ſo as to make 11 feet water at a ſpring tide by the ſide of the wharf, containing 31,300 yards, at 6d. per yard -	783	0	0
To making a groyne or jetee near the ſpace, extending 900 feet, for preventing the ſands from circulating into the harbour - - -	900	0	0
To making a baſon 100 feet ſquare, and laying pipes for keeping the ſand from lying before the wharf - - - -	1,000	0	0
To erecting 5 new dolphins, and other poſts for mooring veſſels; and other contingencies - - - - -	500	0	0
To contingencies upon the whole - - - -	2,000	0	0
	£15,934	0	0

SHIELDS DOCK.

ESTIMATE for lengthening the Dock at North Shields, fo as to make it in the whole 237 Feet Length between the heel of the prefent Gates and the crown of the Arch at the upper end of the Dock; and alfo for the erection of a pair of interior Gates, as per Defign of John Smeaton.

			£	s.	d.
TO digging out the upper ftratum fuppofed pan rubbifh to the mean of 9 feet deep, the ground being opened 63 feet wide at top, and to be 60 feet wide at bottom of faid depth, will contain	cube yards	2133			
The lower ftratum fuppofed a clayey fand		2246			
Total excavation digging 6d. loading at 3d.		4379 at 9d.	164	4	3
Drainage of the water, fuppofe 4 men employed at a time, that is 8 men for 24 hours, and this continued for three months or 90 days at 18d. per man per day			54	0	0
To leave for laying the ftuff			25	0	0
Clearing the foundations			£243	4	3

CARPENTRY IN THE FLOOR.

			£	s.	d.
To 1 pile per yard running under the ftring piece in the front of the wall, being 9 inches diameter, and 9 feet long, of beach, elm, alder, or fir timber, will be in number		81			
To 2 piles under the middle of each beam or groundfell, which, if at 3 feet diftance, will be		70			
To piles, timber, making and driving		151 at 10s.	75	10	0
To 35 beams or groundfells at 3 feet diftances middle and middle, 33 feet long 12 × 12 containing	cube feet	1155			
To 242 running of ftring piece 12 × 6		121			
To timber and workmanfhip		1276 at 1s 9d.	111	13	0
To 2 piling machines at £3 each			6	0	0
To tranails of 18 inches long for the ftring pieces 81 at					
To do 24 groundfells, 70 at					
To 3332 feet fuperficial of 3 inch fir plank for the floors, timber and workmanfhip at 6d. per foot			83	6	0
To caulking ditto at per foot fuperficial					
To 13 cwt. of fpikes at 36s.			23	8	0
Carpentry in the foundations, exclufive of trenails and caulking			£299	17	0

	£	s.	d.
To ramming in between the walls fells, with a mixture of clean London ballaft and quick lime, containing 83 cube yards, at 1s.	4	3	0
To flufhing the fame with a layer of pozzelana mortar, to lay the planks upon, containing 259 fquare yards, at 7d.	7	11	1
To filling in the foundations	£11	14	1

MASONRY.

	£	s.	d.	£	s.	d.
To aifler in the fide walls, which at the mean thicknefs of 2½ feet, will contain 12,352 cube feet, which winning, leading, and hewing, at 7½d. per foot				386	0	0
To pozzelana mortar for fetting the fame ¾ per foot, including extra labour				38	12	0
N. B. 14 tons of pozzelana mortar will be wanted at £2 2s. per ton.						
To rubble ftone for backing 1148 yards of 2 feet thick, which will take 1435 fodders of ftone, which winning at 3d. leading at 1s. is 15d. per fodder				89	13	9
Mortar for do.						
To 162 fodders of lime at 6s.	48	12	0			
To do. of pan rubbifh fifted, at 10d.	6	15	0			
To 100 tons of fand at 6d.	2	10	0	57	17	0
To fetting 12,352 cube feet of aifler, at 1d.				51	9	4
To building 1148 cube yards of rubble, at 1s.				57	8	0
Mafonry in the whole				£681	0	1

	£	s.	d.
This comes to 7s. 5d. per the reduced yard upon the whole folid, the mafon faid it would be done for 4s.			
To moating the fame with clay, containing at one foot thick, 4838 cube feet at 2d. including the filling in and making good the earth behind the walls	40	6	4

CARPENTRY IN ERECTING THE GATES.

The Threfhold and Barrier at the Gate Heels.

	£	s.	d.
To 185 cube feet of oak and elm timber, timber and workmanfhip at 3s. 6d. per cube foot meafured neat in place	32	7	6
To fir timber, 133 cube feet, meafured neat in place, at 2s.	13	6	0
Threfhold and barriers	£45	13	6

THE

THE GATES.	£	s.	d.
To oak for the two heel posts, and clapping posts, 78 feet, at 4s. timber and workmanship included, neat measured in place - - -	15	12	0
To 52 oak keys for the gate bars at 1s. - - -	2	12	0
To 504 cube feet of fir timber, in the gate ribs, timber, workmanship, and measured neat in place at 2s. 6d. - - -	63	0	0
To caulking - - - - - - - -			
Carpentry in the gates - - -	£ 81	4	0

IRON WORK, &c.

In fixing the threshold and barriers.

	£	s.	d.
In jagged bolts and anchor at 4d. per lb. 3 cwt. 2 qrs. - - -	6	10	8
In screwed bolts and straps for fixing the main posts, braces, &c. at 5d. 3 cwt. 1 qr.	7	11	8
To spikes for putting on the ribbands and planking, at 36s per cwt. 1 cwt. 2qrs. -	2	14	0
Fixing the dormant part - -	£ 16	16	4

IN THE GATES.

	cwt.	qr.		£	s.	d.
To 20 pair of T and L's, weight -	7	3	0			
To 2 long screwed bolts - -	2	2	0			
	10	1	0 at $4\frac{1}{2}$d per lb. - -	21	10	6
To 2 hoops for the top of clapping posts -	1. $\frac{1}{2}$ at 4d.		- -	0	14	0
				£ 22	4	6

Hinges for the Gates, &c.

	cwt.	qrs.		£	s.	d.
The pair of upper hinges -	2	1				
The 2 heel hinges - -	1	3				
	4 cwt. at $4\frac{1}{2}$		- - -	8	8	0
To 2 cast iron beds for holding the gudgeon and forming the heel circle, 5 cwt. 1 qr. at 18s. per cwt. - - - - - - -				4	14	6
To 2 copper plates, each 1f. 6i. long, 1 foot broad, and about $\frac{1}{8}$ inch thick 22lb. at 16d.				1	9	4
Work for the gates to turn - -				£ 14	11	10

ACCOUNT received from Mr. Walton, after making the Estimate, of the following Articles, not charged for want of knowing the customary price, viz.

	£	s.	d.
81 trenails, 18 inches long, including labor, at $1\frac{1}{4}$d. - - -	0	8	$5\frac{1}{4}$
70 do. 24 inches long, including labour, at 2d. - - -	0	11	8
Caulking the floor of the dock, 3332 feet, including oakum, pitch, and labour at 2d.	27	15	4
Do. the dock gates, 576 feet, including do. at 2d. - - -	4	16	0

ABSTRACT

ABSTRACT of the preceding ESTIMATE.

	£	s.	d.	£	s.	d.
Digging, drainage, and clearing the foundations - - -				243	4	3
Carpentry in the foundation, exclusive of trenails and caulking - -				299	17	0
To filling in the foundation - - - - -				11	14	1
The foundation - - -				£ 554	15	4
Masonry in the walls - - -	681	0	1			
To moating with clay, and filling in behind the walls	40	6	4			
			-	721	6	5
Total expense of lengthening the dock - -				£ 1276	1	9

ERECTING THE GATES.

	£	s.	d.	£	s.	d.	£	s.	d.
Carpentry in the thresholds and barriers -	45	13	6						
Do. in the gates - - - -	81	4	0						
			-	126	17	6			
Iron work in the threshold and barriers -	16	16	4						
Do. in the gates - - -	22	4	6						
Hinges and work for the gates to turn upon -	14	11	10						
			-	53	12	8			
Erecting the gates - - - - - -							180	10	2
Net estimate - -							£ 1456	11	11
Allow for contingent articles not included in the foregoing estimate, at the rate of 5 per cent - - - - - -							72	16	7
							£ 1529	8	6

Austhorpe,
6th *May* 1775.

J. SMEATON.

TREWARDRETH HARBOUR.

The REPORT of JOHN SMEATON, Civil Engineer, upon the Queſtion of a Harbour in the Bay of Trewardreth, Cornwall, exhibited by Brooke Watson, Eſq.

THE deſign for a baſon and an entering veſtibule before me for Trewardreth Bay, appears to me ſufficiently well imagined as to its ſhape and poſition, reſpecting the points of the compaſs and the adjacent coaſt; but the entering veſtibule, which I apprehend is principally intended to ſhelter the gates, whereby the water of the baſon is to be held up to its deſtined height, appears to me by far too ſmall to produce that effect. In this area I have drawn a circle of 100 feet, that is of 33 yards diameter; and the whole area will ſcarcely amount to a quarter of an acre. It does not ſignify what, or how great the area of the baſon may be within the gates; becauſe this will have no influence on the quieting the outward port or veſtibule; and therefore, ſuppoſe a ſea runs in with a ſtrong wind at S. E. (I mean right into the opening), and is therein reflected from the different piers and walls, it will manifeſtly tend to the deſtruction of the gates; as from the meaſures they muſt neceſſarily be placed ſo near theſe walls, and receive their ſtrokes in one direction or another, ſo very frequently, that I do not apprehend any timber work upon that ſcale will be found ſtout enough to endure the ſhocks for a length of time.

If the neceſſary occaſions for the ſize of ſhips were leſs in proportion, as it might be more uſeful to lay out a leſs capital upon a project of this kind, then, as the entry of a port might be made leſs in width, in the ſame proportion as the ſhips themſelves were leſs, it might perhaps be brought about, that a ſmall harbour could be rendered as quiet as a large one; but ſince the neceſſary occaſion for width in the entry of the port, is not ſmaller in proportion as the area of the harbour is ſmaller, but to the width of the largeſt ſhip intended to enter it, then a very ſmall port may have an occaſion for as wide an entry as a large one; and conſequently the quietude of the ſhipping lying therein, will be leſs (perhaps in a greater proportion) than the increaſe of width, to that of its area.

I do not know that it has yet ever been aſcertained, what is the greateſt width to be admitted to the entry of a port, in proportion to the number of acres it contains; or what amounts

amounts to nearly the ſame thing, what will be the proportion between the width of the mouth of the port and the mean diameter thereof. In the preſent caſe the width of the entry is thirty feet, that of the area of the veſtibule about 100; that is a little more than one to three; certain it is that I do not recollect ever to have ſeen the area of a port ſo confined, where it has been encloſed with a wall; and where a large pair of gates are to be protected, I ſhould imagine the internal ſpace ſhould be far greater. I ſhould think a mean diameter of 300 or rather 400 feet quite little enough, or the veſtibule ſtill preſerving the width of thirty or at moſt thirty-five feet to the mouth; and even this mouth will be quite little enough to admit a veſſel of twenty-ſeven or twenty-eight feet to enter with tolerable facility.

It being ſuppoſed that the figure of the outward harbour or veſtibule is near upon right, its dimenſions may be increaſed in any proportion; and if there were a want of ſpace, a part of the propoſed area of the baſon may be taken into the veſtibule: True; but here will be a great addition to the walling in proportion to the area of the baſon, and capacity for the entertainment of ſhips.

I think it my duty to ſuggeſt, that every part of the works expoſed to the ſea in the bottom of this bay, ought to be done in the moſt ſubſtantial manner, otherwiſe failures may be expected; and how far the occaſions of trade in this place will render it a profitable undertaking, to encounter the neceſſary expenſes ſhould be well conſidered before the execution is reſolved on.

It is generally allowed that Milford Haven is one of the moſt complete natural harbours in this kingdom; but let it be reduced by a ſuitable ſcale to two or three acres of area, and the width of its mouth reduced from three or four miles, to thirty or forty yards; it will then become a much more unſuitable deſign for a harbour than this under conſideration.

J. SMEATON.

Grays Inn,
18th *January* 1792.

JERSEY HARBOURS.

(See Plate 9.)

To the Right Honourable his Excellency the Governor, Lieutenant Governor, Lieutenant Baillie, and the Magistrates composing the Committee for the Improvement of the Harbours of Jersey.

The REPORT of JOHN SMEATON, Civil Engineer, upon the Harbours of St. Helliers and St. Aubin.

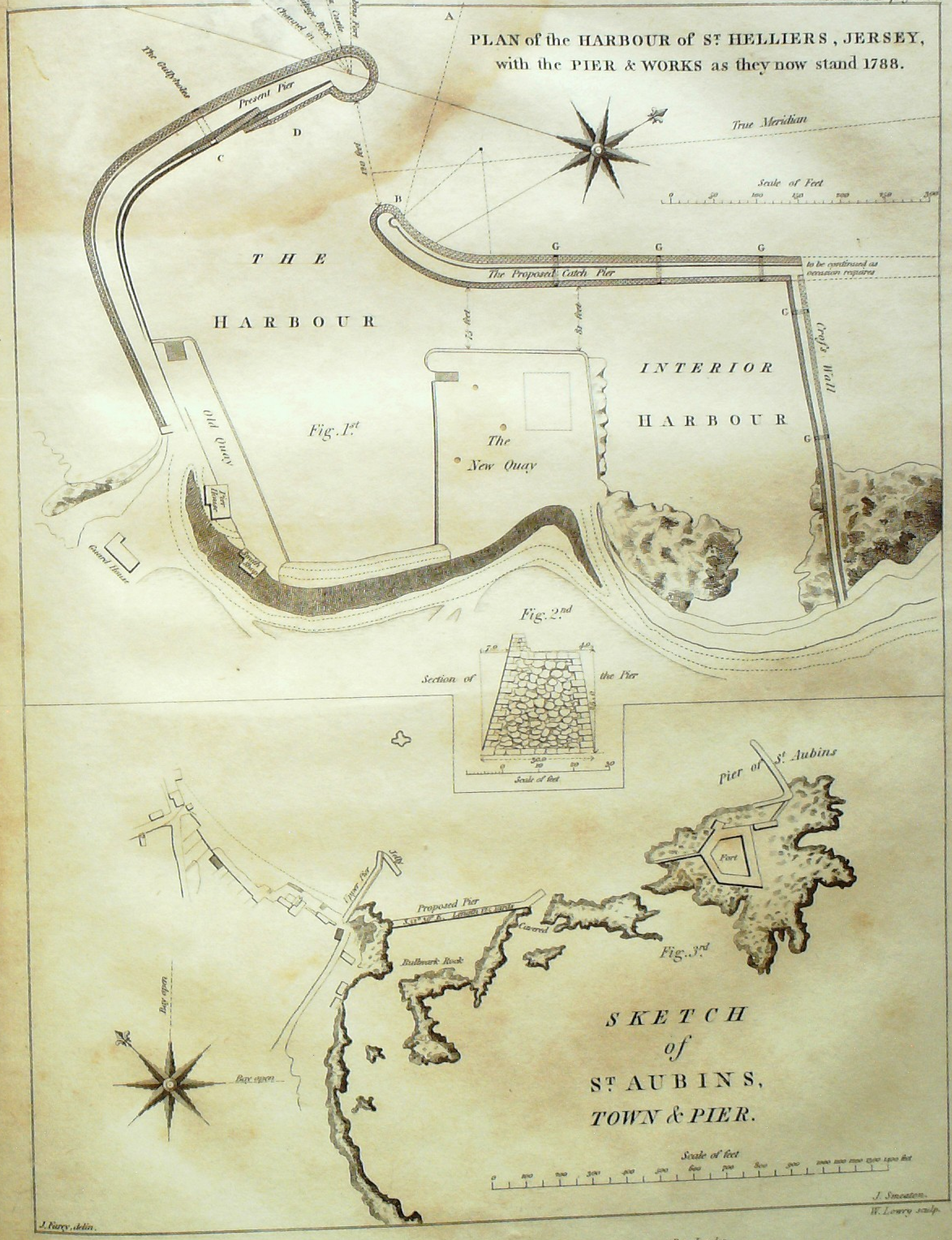
HONOURABLE SIRS,

HAVING at the requeſt of the honourable the Governor, made a voyage to Jerſey upon the ſubjects above ſpecified; and having perſonally reſided in that Iſland from the 5th to the 13th of June laſt, both incluſive; and having during that time diligently obſerved and conſidered whatever appeared material, in conſequence of the matters given me in charge by the honourable Committee above mentioned, I beg leave to report as follows: ſtating firſt, the principal matters reſpecting the harbour of St. Helliers.

That with reſpect to the harbour of St. Helliers, the matters of complaint ſtated were, want of capacity for holding veſſels; and want of quietude when lying therein.

The pier of St. Helliers appears to be of the conſtruction that may be properly denominated a ſcreen; being a work of that kind, where, in the firſt formation, the greateſt degree of ſhelter may be procured at the leaſt expenſe; it has therefore the advantage of doing, in its origin, the greateſt quantity of work for the leaſt money; and were this form attended with no diſadvantages, this would in all caſes be the moſt proper way of proceeding. But as this kind of pier naturally turns its back towards the ſea, and its mouth towards the land, upon the ſuppoſition of a ſloping ſhore as commonly happens; if an extenſion of the pier is wanted for an enlargement of the harbour, it naturally brings the entrance into ſhallower water; whereas, when piers are extended from the ſhore towards the ſea, a further extenſion of theſe piers naturally gains deeper water.

The pier of St. Helliers having been fixed and ſupported at a conſiderable expenſe, in proportion to the funds of the iſland, it would be uſeleſs to conſider how it ought to have been



Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row London.

been planned, were every thing at this day in a ſtate of nature. The propoſition is to make the beſt uſe of it, as it now ſtands; and conſidering it as a part of a whole, to procure at the leaſt expenſe, more room and better ſhelter.

Had it not been for the ſhoaling of the water at the entry, the firſt thing that would naturally ſtrike, would be to extend the preſent pier further to the north, and to meet it with a catchpier from the north-eaſt corner of the new quay. This contracting the great width that the mouth bears to the capacity of the harbour, would at once render it more ample and more quiet, and would be the moſt eaſily done, as the materials for both piers could be carried progreſſively from the ſhore, but in the opinion of the pilots, as well as the committee and gentlemen conſulted upon the ſpot, the ſhoaling of the water is an invincible objection; in which opinion on full conſideration I find reaſon to concur.

Of the number of plans exhibited to me, that had been the fruits of the ſtudy of different gentlemen of the iſland, the idea moſt generally adopted was, to begin a pier, detached from the preſent, at ſome point betwixt the preſent pier head and the new quay, leaving about 120 feet or upwards of opening betwixt the preſent and new pier head; then carrying it on in a ſtraight direction, ſomewhat near parallel to the face of the new quay, to leave a ſpace between the new pier and the new quay for veſſels to lie; and by extending it northward in the ſame direction towards the town, as the funds for carrying it on admit, to give it every ſuitable enlargement that the occaſions of trade may now or in future require.

This idea in its general outlines and purpoſe ſeemed to me well adapted to the occaſions of the Committee, but yet was likely to be ſubject to one capital inconvenience. I was told that when the wind was at N. W. which point being clear of Elizabeth Caſtle and rocks, the fetch of the ſea, then lying open from the whole extent of St. Aubin's Bay, in blowing weather, cauſes the veſſels to ride unquiet in St. Helliers harbour. Now any pier carried on in any direction parallel to the face of the new quay, or trending more weſtward, will have a great effect to bring the waves that will neceſſarily range along the face of it with ſuch a wind, directly into the mouth of the harbour; and if to avoid this, it has a bearing given it more eaſtward, will confine the additional room propoſed to be made in the harbour between the new quay and the town, ſo near the ſhore, that the depth of water as well as room therein will be too much curtailed. A further objection is, that when veſſels are coming for the harbour before the wind, through their proper channel, or opening through the rocks, which as I underſtand lies at W. S. W. from the pier head; or coming with any ſcant wind, from that point to the S. E., after turning

ing the head to go into the harbour, they will have the wind in their teeth; and as they may not always be able to ſhoot into the harbour, there will not be ſufficient room to *bring up* before the harbour's mouth, without being in the way of thoſe that may follow them under the ſame circumſtances. It appears to me therefore that every inconvenience may be avoided, and the deſired end attained, by forming the pier with a curve towards the head, according to the plan I have now the honour to lay before you; and conformable to the idea of which I left you a ſketch on leaving Jerſey, and which being verbally explained to the Committee, ſeemed to give general ſatisfaction.

According to this diſpoſition, the north-weſtern ſeas will meet the curve of the pier towards the head, in ſuch an angle, that they will be turned from the harbour's mouth (as will appear by conſidering the poſition of the north-weſt line A. B. fig. 1.), and not be turned into it, as would be the reſult, if the pier were to be continued in the ſtraight line, or any one parallel to it, and which in this caſe would leave too great a width of mouth for a harbour of this ſize. But this affords ample ſpace to come-to, in the lee of the harbour's mouth, and afterwards warp in at leiſure. It will alſo afford a ſuperior advantage in getting out with north-weſterly winds, by getting under ſail from the preſent pier head.

This, according to my judgment, will be the way to make the beſt of St. Helliers harbour, and furniſh the deſiderata at the ſhorteſt expenſe. Yet it muſt be adverted to, that no ſmall harbour can be made a very quiet harbour; for the magnitude of the waves are ſuppoſed the ſame to all, and the neceſſary width of the mouth for a ſhip to enter the ſame; ſeas then that in a degree will inevitably wrap round the heads, will affect a ſmaller harbour more than a large one, though of ſimilar conſtructions; for the effect of the waves in diſturbing a harbour is greater, in proportion as the lineal width of the mouth is to the whole area of the harbour. In this reſpect the harbour of St. Helliers is, and always muſt be, defective. Another circumſtance tends much to render a harbour unquiet, and that is, when they are boundered with walls. The waves of the ſea follow the laws of the pendulum, which when once ſet a vibrating would never ceaſe, if not ſtopped by friction and the reſiſtance of the air. The ſame would happen to the libration of the water if there were nothing to ſtop it; for meeting with walls and objects comparatively ſmooth, the waves are not deſtroyed, but reflected into another direction; and from that into another, till they are gradually deſtroyed by friction. The ſpeedieſt way by which waves are deſtroyed (that is by friction) is by forming a ſurf, and breaking upon a ſloping beach, ſand, or rocks; in which alſo the harbour of St. Helliers is defective; there being no part of its circumference, where the ſeas have an opportunity of breaking and ſpending themſelves,

themſelves, the bottom of the harbour excepted, which is a part of the natural ſhore, extending on the S. E. ſide about thirty fathom, betwixt the old and new quays; and which, if opportunity ſhould occur, it would be well to extend. The new quay, which, as I was informed, is principally a cover to rocks, though it ſeems to afford great utility in other reſpects, yet by preventing the ſeas from breaking upon them, will naturally have the effect of rendering the harbour more unquiet; but which, when the new pier is built, will become extenſively uſeful, eſpecially when the croſs wall is formed to the northward, and the north ſide of the new quay is wharfed up.

EXPLANATORY OBSERVATIONS ON THE DESIGN.

THE catch pier as it is here ſhewn extends 520 feet: but I expect that it will have a conſiderable effect in quieting the harbour, by the time it is carried out abreaſt of the north corner of the new quay, that is, from and including the head, to the length of 250 or 260 feet. This will eventually make more room in the preſent harbour, that is, the veſſels can lie cloſer by being more quiet; and will alſo actually increaſe the room by the ſpace betwixt the face of the new quay and the new pier; for then I expect two tier of veſſels may be laid before the face of the new quay, and be ſcreened, not only from the N. W. but all other winds.

When the catch pier is carried out to the length as ſhewn in the plan, the croſs wall built, and the area incloſed freed from the encroaching rocks, then the additional room will be fully double of what can now be occupied. It is true, and I apprehend muſt remain a truth, that the ſands, this way, lie higher than in the preſent harbour; but the interior harbour being conſidered as a place of depoſition, the very great ſpring tides that reign here, (which roſe above low water mark, the ſpring tides when I was there, no leſs than forty feet, though that was a time of the year when the tides in general run ſhort), will enable large veſſels to get into it, and out, for more than a week together during the time of ſpring tides; and though the neap tides here in general run ſhorter than any place I have before had an opportunity of noticing, in proportion to the ſpring tides, being, as I am informed, in general but from nine to ten feet, yet this being conſtantly the caſe with large veſſels in tide harbours, can be no objection here.

Here being no back-water, and the interior harbour a place of great quietude, the ſands may be expected to gather; but to prevent this as much as poſſible, I would recommend an expedient, that I obſerve has been judiciouſly and ſucceſsfully practiſed; and that is, the making low arches or gully-holes underneath and through the body of the

the pier; one of which passes through the same about 200 feet from the pier head. It is about six feet wide and four feet high, so that a person cannot walk under it upright. This aperture has the effect of preventing the sand from lying on the inside in quietude; so that keeping it somewhat disturbed, by the agitation of the seas, it is ready to be hauled out on the retreat of the tide: and I have no doubt, but that it has greatly contributed to prevent the sands being lodged in the harbour to a greater height than they are, and their gradual increase; for I observe the ground of the harbour at and near the interior mouth of the gully, at C. is full eighteen inches lower than the ground at D. being the point equally distant from the gully and the pier head. Were this stopped up, I have no doubt but that in a little time the ground there would become higher.

In this view of keeping down the sand I would recommend gully-holes to be made in the catch pier, at the distance of 120 feet, and disposed as pointed out in the plan at G. G. This will make four gullies in the main body of the pier, and two in the cross wall; but being frequent, I would not advise their being above four feet wide, and three feet and a half high in the crown; and the effect of the first will be so pointed out, before a second is needed to be pitched, that if the dimensions I have assigned, should be too large or too little, the effect will speak for itself, and be remedied in the subsequent *.

With respect to the construction of the pier, I would recommend it to be built with rough granite, in the same manner and style of workmanship as the works of this harbour have already been carried on. I would recommend it to be filled with rough quarry stones to the middle, without any intermixture of gravel or rubbish. The height of the platform at top of the pier I suppose to be the same as the new quay; and as I do not suppose it a place of business, it is very possible it may do without a parapet; but if on raising it to that height, experience shews one to be wanted, it can be added at pleasure. For that reason I have not supposed any stairs, as strong upright ladders bolted to the walls at proper places, will be a sufficient convenience for the purpose. The construction and dimensions of the pier will sufficiently appear by the detached plan and section (fig. 2.); and as there always occurs a difficulty in turning the convex parts of pier heads when composed of rough stones, that is, so to tye in the stones so as not to be fetched out by the surge of the sea; in the plan that I have given of the ground course of the pier head, I have shewn the manner in which I directed the catch pier head of Aberdeen † to be formed, which is also of granite; that is, with anchor stones and dove-tails, somewhat upon the idea of the dove-tail work of Edystone lighthouse.

* It is possible that some of these may be of disservice, while others are of service, in which case the former can easily be walled up.

† The reader may refer to this plan in the third plate, page 49 of this volume.

If

If it could be afforded, it would be well to form every course in this manner; but I apprehend it may be sufficient to do this at every five feet in height; so that beginning with the first course that rises above the ground, there will be six courses bonded in this way; and which will be completed by sixty anchor, and sixty-six dove-tail stones, and which, if not more easily had elsewhere, will be undoubtedly afforded by the quarries of Montmado. Though in the plan they are somewhat regularly disposed, yet they are no ways required to be of equal sizes; all that is wanted will be, that each stone be adapted to its next neighbour.

A very material article that remains is the expense of the work; but this being entirely local it is not possible for me to give any specific estimate, but what would be likely to do more harm than good, for if the price assigned by me be too large, the workmen would endeavour to take advantage of it; and if too small, they would not be bound by it; and the Committee not so well satisfied in not getting the work done at the rate given out. But it will be very material and useful to know, that in the first 240 feet, or sixty fathom of pier, including the head, and supposing the mean height, including the foundation, to be thirty feet, that this pier will contain 9,500 cube yards of work; and as I estimate it, will take 19,000 tons of rough materials, exclusive of the parapet.

THE HARBOUR OF ST. AUBIN.

RESPECTING this Harbour the following matters having been submitted to me in writing, I cannot acquit myself better than in giving distinct answers thereto. The paper is as follows:

“ Experience having shewn that the new pier of St. Aubin, called the Upper Pier, intended to bring and lay up ships and vessels close to the town, for the convenience of fitting them out, loading and unloading, is from its situation liable to fill, by the great quantity of gravel which the sea washes in from the back of it; and that the depth of water is, from that action of the sea, diminishing more and more; it has therefore been conceived that the building, instead of this, another pier further out to reach from the point of land called the Bulwark, to a rock called Cavard, in the direction of the fort, will answer every purpose of security, convenience, and greater depth of water, and is not so likely to be exposed to fill as the other.

“ k

"It has also been found that the want of a proper road for carts to communicate with the aforesaid pier during the hours of high water in spring tides, is a real inconvenience; as in that circumstance, carts cannot have access to the pier, without going round a part of the town, and up and down again a steep road; wherefore it would be desirable, to procure a proper road by taking upon the harbour, such an extent as may not be prejudicial, and obtaining by that means the additional advantage of a quay or wharf, against which boats and other small craft could be brought up at high water, to take in and out things upon occasion.

"But as it is found by observation that men who want professional knowledge and experience, in respect to the effects of buildings for harbours, and to oppose the sea, are subject to be disappointed in the works they project; it is therefore wished Mr. Smeaton would well consider the above stated work, and give his opinion.

"1st. Whether this new projected pier instead of that now subsisting, is the most eligible plan which can be adopted to remedy the inconveniences of the other? And if not, What other expedient he would advise?

"2dly. In case Mr. Smeaton approved the said plan, Whether it is most advisable to commence the work at the extremity towards the sea, and to continue it towards land to a certain degree of forwardness, before the old pier or any part of it be taken down?

"3dly. Whether he would advise the taking upon the harbour, and in what extent, in order to acquire the road and convenience above stated? And whether this work of the road and quay ought or ought not to be begun, before some progress is made in the building of the intended pier?

"N. B. The time the want of this road is felt, is for the space of about two hours in the mornings and evenings of spring tides.

"Mr. Smeaton is also requested to impart such further advice upon the whole as his skill and experience may suggest."

Answer to the 1st.—As I look upon it the reason why the upper pier, as it stands at present, becomes liable to fill with gravel, arises from this circumstance; that the west end of the island of Jersey lying open to the fetch of the great seas propagated from the Atlantic Ocean, there being no land to shelter it in that direction, that is from the W. S. W. to W. N. W. (according to the true meridian), great seas, of course, with all westerly and south westerly winds, will rake the shore from the Corbiere to Noirmont Point; and turning that, south westerly winds will drive forward the gravel brought along with it coastwise, towards the bottom of St. Aubin's Bay; and in its way meets with the upper pier now erected; but this pier not extending far enough from the shore effectually to intersect

intersect and intercept the course of the gravel, thus continually and successively brought, it is driven round the pier head; and there finding an eddy (which will constitute a place of repose on the north side of the pier), will naturally produce the annoyance complained of. Nor does the effort made use of, appear likely to stop the current of the gravel; for the jetee being low, and pointing directly across its course, the gravel was driven over it, and round it, and the jetee itself in a great measure destroyed. Had the materials employed in erecting this jetee, been applied to carry out the pier head in its N. E. direction, this, flanking the current with a considerable obliquity, would have probably had a perceptible good effect, and had the head been lengthened to its full height, to as great a length in addition as that of the jetee, in all probability this would have in a good part relieved the complaint. I say in a good part relieved it, for the upper pier being too much in shallow water, to fully answer the purposes of business, I am of opinion that nothing can more effectually tend to relieve the complaint, and answer the purposes intended, than a removal of the pier, and carrying it out in the direction and extent proposed in the plan exhibited to me; which was, to carry it out from the Bulwark rock, in a direction towards the fort; that is, S. 52° 30′ E. to the length of 175 yards, or 525 feet; and afterwards in the direction S. 69° E. to the length of 105 feet: in the whole 630 feet.

To the 2d.—I apprehend the place of beginning will depend upon the situation of the principal and weighty materials. If they are to be brought or floated by water to the place, then they can be best deposited at the pier head; and carrying on the work towards the Bulwark rock, to that degree of forwardness that the new pier becomes a shelter, which experience will point out; then the materials of the present pier may be removed, to fill up the gap and join the land. But if the materials are principally to be brought from the land, then the beginning from the Bulwark rock and advancing forward progressively, will be found to be the easiest and cheapest mode of proceeding, as well as the safest from derangements. And thus carrying the work forward till an equal shelter is found to what is afforded by the present pier; then this last may be begun to be removed, in order to carry the other work forward; beginning in taking down with the pier head. I think there is this objection to the beginning at both ends, as then there will be two unfinished terminations, always lying open to the derangements of storms.

To the 3d.—I must observe, that a degree of inconvenience will always be outweighed by a superior utility. In my discourse upon St. Helliers harbour, I have fully pointed out, that where a sloping shore is interrupted by the erection of a wall, as a wall has not that tendency to spend and destroy the waves of the sea that a sloping shore constantly has; wherever walls are erected in the confines of a harbour, it is rendered, in a degree, less quiet

quiet by this means. That there will be a difference is evident and demonſtrative; but degrees of quietude not being meaſurable by a ſcale, it is not always poſſible to ſay what will be the degree of difference. The want of a road to a harbour acceſſible at all times of tide, is a capital defect; but to the remedy propoſed, of taking ſuch a breadth from the harbour as may not be prejudicial, the whole that can be ſaid, is, that as the road muſt be formed and ſupported by a terminating wall towards the bay, while you are gaining a greater breadth, you are wanting a higher wall; and a higher wall when there is water before it, will more ſtrongly reflect back the waves, inſtead of deſtroying them; and thoſe meeting with, and compounding themſelves with others, will moſt undoubtedly render the harbour more unquiet, than if things were, in this reſpect, to remain as they are. Again, the more uſeful this wharf wall is made, for laying ſmall boats and craft againſt it, by a depth of water before it, the more it will tend towards general inquietude; and unleſs in calm and quiet times, as the face of this wall will lay open to the bay towards the eaſt, I believe thoſe boats will not find it very eligible to lie againſt it. But yet a road is ſo great a convenience, that if forty or even fifty feet of frontage be taken from the ſhore, before the moſt projecting wharfs (I mean thoſe ſouthwardly towards the pier), as they at preſent ſtand; and the wall is carried in a regular curve from thence to join the projection where the road aſcends the ſtreet; I ſhould apprehend, as this can be wharfed up with a wall of a few feet in height, that its influence at the diſtance to which the new pier is propoſed to be erected, will not be ſo material as the convenience; but whatever that influence may be at that diſtance, it certainly will be greater at the diſtance of the preſent upper pier, which is much nearer. There poſſibly might be conveniences and motives in having this road made now, which might make it worth the while to hazard even this difference. But as it does not appear to me, that the want of ſuch a road for two hours a day, for four, or at moſt five days at each ſpring tide, can be of great conſequence; ſeeing that at thoſe times, the low water is in the middle of the day, and the interruptions can therefore be only at mornings and evenings, the reſt of the day being free of acceſs; and furthermore, that in caſe of need, the pier is acceſſible at all times by a road that hitherto has been practicable; all theſe things conſidered, I cannot recommend to begin the road and wharf, till ſome progreſs is made in the building of the intended pier; or to do any thing that may in its effect be hurtful to the preſent ſituation, till a better one is acquired; and the appearance of the benefit, more ſubſtantial than the riſque.

I am, honourable Sirs,
Your moſt humble ſervant,
J. SMEATON.

Grays Inn, London,
30 *Sept.* 1788.

QUEENSFERRY SHIPPING PLACES.

The REPORT of John Smeaton, Engineer, upon the Shipping Places at Queensferry, in the Firth of Forth, from a View taken the 15th of August 1772.

IT ſeems ſcarcely neceſſary to ſay any thing upon the importance of this ferry: it being the ſhorteſt and moſt commodious place of croſſing the Firth of Forth, and thereby muſt recommend itſelf to the attention of every one who has concern in and wiſhes well to the kingdom in general; and on occaſions is, and may be made more ſerviceable for the paſſage of troops, could a bridge be built at this place, though at the expenſe of £100,000, I apprehend it would become a national object to conſtruct it; but as we cannot hope to ſee this effected, the next beſt thing is a commodious ferry; and if it would be worth ſo large a ſum to obtain a bridge, it would ſurely be worth a conſiderable ſum to obtain the moſt commodious ferry poſſible. As matters now ſtand, there appear to be good veſſels well adapted to the purpoſe in ſufficient number, and very able and expert hands to manage them; and even in its preſent ſtate, from what I have experienced of it myſelf for years paſt, I believe it may be ſaid to be one of the moſt commodious and beſt attended ferries of the width in Great Britain. The principal defect is in the ſhipping or landing places of embarging and diſembarging paſſengers, carriages and cattle; what conveniences of this kind there are already are in a great meaſure furniſhed by nature, and the diſadvantages thereof are ſuch, as where nature requires a little aſſiſtance from art.

The principal defects ariſe from the roughneſs and awkwardneſs of ſome of the preſent places, for want of proper ſhelter in particular winds and times of tides, but principally for want of any proper ſhipping place at all, at or near the low water of a ſpring tide; by which travellers are often detained when the wind is fair, and afterwards further detained by the winds coming foul.

There are ſeveral places of ſhipping on each ſide, but moſt of all upon the ſouth ſide, and the ſkippers make uſe of theſe as occaſion ſerve; and in fact it is more commodious to have various places on each ſide than to be confined to one on each ſide though ever ſo complete, becauſe from the courſe of winds and ſet of tides, they can frequently make their way good between two places without tacking, when they cannot do it between others without great loſs of time, and *vice verſa* in other ſets of winds and tides.

The

The principal ſhippings on the ſouth ſide are as follow :

The Binks being the weſtermoſt and oldeſt ſhipping place ; it fronts the weſt, and therefore moſt proper in eaſterly winds ; it extends to high water.

The Grey Shipping lies near to low water, and is of uſe only when the water is low.

The Foreneſs Shipping fronts eaſt, therefore propereſt in weſterly winds, and ſerves from ſomewhat below half flood to high water.

The Weſt Hall fronts eaſt, therefore propereſt in weſterly winds.

The Long Craig fronts weſt, therefore propereſt in eaſterly winds ; this is chiefly uſed when the tide is low.

The White Houſe fronts and is nearly ſimilar to the former, being further to the eaſt.

North Ferry.

Craig End, the principal ſhipping place, anſwers to both eaſt and weſt.

The Weſt Neſs fronts the weſt, therefore propereſt in eaſterly winds ; is uſed chiefly when the tide is low.

The Wich or Eaſt Neſs fronts the eaſt, and therefore beſt in weſterly winds ; this ſhipping ſerves at low water, but is at preſent very difficult of acceſs.

On communing with the ſkippers as well as the principal perſons at South End and North Ferry, I am of opinion that the ſhippings which are of the moſt immediate conſequence to improve are the Grey Shipping contiguous to Queensferry harbour and the Weſt Halls on the ſouth ſide, and the Craig End and the Wich on the north ſide.

The Grey Shipping ſeems to have been formerly attempted or made a place, but has been either deſtroyed by ſtorms or left imperfect ; there is a good maſs of ſtones upon the place, but will need a conſiderable addition to make it regular and proper ; it will be right to make a face both eaſt and weſt, and then it will be proper for winds either way, and to build it ſloping from low water, to anſwer ſuch time of tide as the Fore Neſs begins to take place, which ſerves to high water.

The Fore Neſs ſhipping wants ſome repair, and it would ſeem better if it was made ſtraight and the jetees taken away near the lower end ; but that is not ſo immediately neceſſary as the Grey Shipping.

The

The Weſt Halls is chiefly a natural ledge of rocks, ſtanding from low water to high water ; the rocks here want part facing, part building, and part levelling ; the height of this above the ſand ſhould not be leſs than five nor more than ſix feet.

Some little help is wanted to cut down the face of the long craig from whence it has been begun to low water, in caſe funds ſhould not hold out after the work at Weſt Hall is done.

The craig end at North Ferry has had the moſt improvement made thereon of any of the reſt, and indeed ſeems the moſt important ; but the work wants to be extended to the turn of the point, by which means near two feet addition of water will be gained. This ſhipping however will not extend to the low water of a ſpring tide, it is therefore of importance to improve the Eaſt Neſs ſhipping, which has plenty of depth at low water, and is very commodious in weſterly winds, and in all other winds that do not overblow. The principal thing wanted here is to ſmooth down the rough rocks in order to form a road which in its preſent ſtate ſeems quite impracticable for carriages and horſes ; this may be done by blowing away the irregularities of the rocks, or by bolting down timbers to take the wheels of carriages in the manner of a rail road.

The great irregularity of each of the places that want improvement, makes it not eaſy to get ſuch meaſures as would be neceſſary to form any eſtimate that can be depended upon without the whole was lined out upon the ſpot, which would take up much more time than my occaſions could poſſibly allow. But upon a general view of the thing, I am of opinion that if the ſum of £500 were raiſed and diſtributed amongſt the three places mentioned, viz. the Grey Shipping and Foreneſs, the Weſt Halls and Long Craig, and the Craig End and Eaſt Neſs at North Ferry, the improvements that would be made under prudent management would be ſuch as would be of real uſe to the public, and demonſtrate that ſuch further ſum as might be neceſſary to make the whole complete, would merit the aid of thoſe who are enabled to give it.

J. SMEATON.

Edinburgh
26th *Auguſt* 1772.

P. S. The length to be made at the Grey Shipping is 96 yards.
That at the weſt halls - - - 142 do.
The addition at Craig End, about - 53 do.

And a buoy anchor and chain would be very uſeful to be laid at a convenient diſtance off the craig End, to enable the veſſels better to haul off and get under way in contrary winds.

J. S.

EDINBURGH BRIDGE.

The REPORT of Meſſrs. SMEATON, ADAM, and BAXTER, concerning the Bridge of Edinburgh, addreſſed to the Right Honourable the Lord Provoſt, Magiſtrates, and Bridge Committee of Edinburgh.

HAVING been called upon by you to give our opinions concerning the bridge of Edinburgh, in conſequence of the unhappy accident that happened thereto upon the third of this preſent month, we have in conſequence each of us minutely examined the ſtate thereof with all the attention we are able, we have alſo carefully conſidered every matter of fact that has been laid before us in way of evidence concerning it, and we have fully heard and conſidered every thing that has been offered and propoſed to us by Meſſrs. Mylnes towards the effectual reparation and reſtoration thereof; and upon the whole matter we are of opinion as follows:

That not only the particular accident which has been the occaſion of this enquiry, but every other matter of a leſſer kind of which we have found this ſtructure complaining, has been cauſed by an overload of earth upon the upper parts thereof, and therefore in general that though the effects of this over preſſure has become evident by ſetts in various parts of the building, yet if the whole be eaſed of this overload, and properly bonded together, we apprehend that relative to a leſs weight, the remaining parts of the ſtructure may be rendered firm and ſecure.

We beg leave to obſerve by the way, that all heavy buildings are more or leſs obnoxious to ſetts, and particularly thoſe where great weights are obliged to reſt upon ſmall areas of ground; yet we ſee buildings ſtand for ages under thoſe circumſtances much more than thoſe caſes where they can be relieved of the preſſure which has originally occaſioned thoſe derangements, and we muſt further obſerve that though this bridge were to be taken down and rebuilt with all the ſkill of Europe, yet it cannot be enſured, but that ſomething of this kind would appear.

We alſo beg leave to take notice, that the particular accident upon which we have been called, is of a very uncommon nature, viz. the falling in of the three vaults in the ſouth abutment: we can infer in the general that this has been occaſioned by an over preſſure, but

but by what particular circumſtance it has happened that the arches of thoſe three vaults have given way in ſo ſudden and ſo alarming a manner, we cannot at preſent inveſtigate, but which perhaps will be more fully diſcovered when the rubbiſh is removed; this however we infer from it, that as it does not appear to us that the three great arches, with any of their connections northward, have ſuffered any alteration by the ſudden and even momentary deſtruction of the ſouth abutment, thoſe arches muſt in conſequence be very well poiſed upon their own legs.

Such being the general cauſes, and ſuch the general remedies, we come now to the particulars, with the method of reparation pointed out to us by Meſſrs. Mylnes, with our obſervations thereupon.

To remove the great overload of earth, Meſſrs. Mylnes ſuggeſt may be effected by ſhaving off two feet of ſolid earth from the whole ſurface of the bridge.

This will certainly have a very good effect in the reſpect mentioned, and we ſee no objection to it, ſave that it will cauſe the declivity to be in the whole two feet greater; but we apprehend it will ſtill be ſufficiently eaſy; and that it will in ſome meaſure obſtruct their view ſideways, but we may ſet againſt this, that the ſame two feet relative additional height in the parapets, will make a ſkreen to the violence of the wind, which may be expected in ſome ſeaſons of the year to be too ſeverely felt.

1ſt. Reſpecting that part of the north abutment which is filled ſolid with earth, we obſerve that the wall on the weſt ſide is ſomewhat rounded, which we imagine has been occaſioned by the lateral preſſure of the earth within it relative to the great height of the wall, and as this has doubtleſs happened by laying the earth againſt it, while the wall was green, it may poſſibly go no further; but to make it ſecure, Meſſrs. Mylnes propoſe to raiſe up outſide buttreſſes, as well againſt the eaſt wall as the weſt, which we approve.

2d. Reſpecting the vaults in the north abutment (which are ſimilar to thoſe on the ſouth which fell in, and were the immediate cauſe of the accident above mentioned) we obſerve that the outwalls not being bonded in with the arches, are ſeparated therefrom about an inch, at a medium, at the crowns, and the croſs walls from which the arches ſprung being loaded with a conſiderable thickneſs of earth above them, are thereby preſſed with a greater weight than the ſide walls, and have therefore ſettled, by the difference of from a quarter to half an inch more than the ſide walls, ſo as to break the bond between them. Theſe effects are doubtleſs owing to too great a quantity of earth above theſe vaults, preſſing the walls

walls that ſupport the arches downwards, and the out wall ſideways; but as independent of this preſſure, we ſee no reaſon why the walls ſhould fall, ſuppoſing they had originally been built in this manner, Meſſrs. Mylnes are of opinion it will be proper to lay the greateſt part of the ſpace above theſe vaults hollow by arch work; and alſo to confine the two ſide walls together by chain bars from ſide to ſide, which we approve; and we beg leave further to offer, that we look upon it, that the beſt mode of arching in this place, will be ſimply to raiſe croſs walls upon the former; and upon them to ſpring new arches over the preſent, to riſe as high as the road will admit.

3d. The ſmall open arch on the north ſide ſeems perfectly ſound and entire, Meſſrs. Mylnes therefore think it will be ſufficient to lay chain bars from ſide to ſide to prevent the lateral preſſure of the earth from ſwaying them outwards, till the whole is hardened and compacted together; now as we underſtand, there are already relieving arches over that open arch, we alſo ſuppoſe this to be a remedy ſufficient, provided the two feet reduction of the height of the road be approved of by the Magiſtrates, otherwiſe we think ſomething ſhould be here done by way of avoiding an addition of weight.

4th. The three great arches appear to ſtand firm upon their legs, as they were built, there are however ſome ſplits in particular parts, chiefly in the rubble work of the foundation of the piers, which though proceeding from the unequal bearing that inevitably attends that ſort of work, yet would probably not have appeared, had they not been charged with an extraordinary preſſure; in order therefore as well to relieve the piers with their foundations as to prevent the lateral preſſure of the earth againſt the ſpandrill walls from the chance of producing any ill effect, we cannot but recommend any method of arching in the ſpandrills between the great arches that will effectually ſave weight in lieu of chain bars acroſs the bridge at theſe places.

5th. We come now to the ſmall arch on the ſouth ſide, concerning which the whole of the difficulty lies we underſtand that previouſly to the falling of the three vaults contiguous thereto, there was a ſett or rend of the abutment wall from the top to the bottom, which extended itſelf acroſs the ſmall arch as far as the impoſt of the pier on the north ſide, which rend not only in the abutment wall but in the arch opened conſiderably wider than before upon the fall of the contiguous vaults; in this arch the rend divided into two branches, the former almoſt directly acroſs, and which now affects the piers in a ſmall degree, the new one diagonally towards the north weſt ſpringer. This original rend we apprehend to be cauſed ſimply thus, that the matter of the natural foundation of the abutment wall, being leſs firm weſtward than eaſtward, when the whole became loaded with the

the ſuperincumbent weight of earth before mentioned, the weſt ſide ſettled, leaving the eaſt ſide ſtanding firm, and thereby occaſioned the rend as firſt mentioned. The falling of the vaults we look upon as occaſioned by ſome failure of a different kind; though ſtill owing to the general cauſe of over preſſure, it is not therefore to be wondered that this rend before made, ſhould become worſe by the great concuſſion of ground that muſt have attended the fall of the vaults, with all the matter above them. In this ſtate of things, Meſſrs. Mylnes are of opinion, that it is abſolutely unſafe to take down this ſmall arch, leſt the lateral preſſure of the great arches ſhould by overſetting their piers, bring the whole into ruin; they therefore ſuggeſt that it muſt be remedied by the following artificial means.

To inſert a ſtrong ſpring arch or courſe of aiſler ſtone, diagonally from the lower part of the baſe of the ſouth pier, to the upper part of the baſe of the abutment wall, by which means (as a brace in timber work) the over preſſure upon the foundation of the abutment wall will be diſcharged upon that of the pier, and thereby the dependance made upon the two together. They proceed then to take down the abutment wall, to a proper height below the crown of the arch, and to cap it with ſome courſes of large hewn ſtone, firmly bonded together with chain bars, ſo as to prevent any further ſeparation of the abutment wall, and upon this cap as a baſis to raiſe a wall of a ſufficient height; to ſpring a freſh arch over the former, ſo as to occupy the whole ſpace between the abutment wall and the next great arch, by which means the preſent arch will have nothing to do but to preſerve the uniformity of the appearance, then to draw the fractured and disjointed ſtones to make all fair, and bond the whole together with chain bars in the ſecureſt manner.

To this propoſition we muſt be candid enough to ſay, that if very carefully executed we muſt expect it to ſucceed; but we think ourſelves equally obliged in juſtice to all concerned, to declare, that in our opinion it would be more eligible, and what we would attempt were the caſe our own, to rebuild the fractured arch, and as much of the abutment wall, as can be taken down with ſafety.

To prevent therefore the lateral preſſure of the great arches from taking effect, we would place an additional row of ſhoars in a ſimilar poſition to thoſe now there, which we would ſtep upon the next ſet off, on the abutment wall below the preſent, and inſert them into the ſolid of the pier at about the height of the impoſt of the great arch, thoſe ſhoars to be of whole timber, and to be ſo many in number, that the ſpaces will be only equal to the timbers. This being carefully done and well keyed home, we would take down the ſmall arch, leaving as much of the ſoffite ſtanding on the north ſide as will ſupport itſelf without a center,

a center, and as much of the folid work above as this will fupport, then taking down the abutment wall within two courfes of the bafe, we would lay on two ftring courfes to be of aifler within and without and ftrongly bonded together with chain bars. Upon this as a frefh bafe the abutment wall is again to be raifed to its proper height, and the arch fprung over as before, and then finifhed with an arch of relief as fuggefted by Meffrs. Mylnes. This method to the beft of our opinion may be put in execution with perfect fafety to the great arches, yet we cannot take upon us to fay we can abfolutely enfure it.

6th. Refpecting the rebuilding of the fallen vaults there is the leaft difficulty of all, for if the walls of thefe vaults are raifed fo high that the crowns thereof do properly clear the road, we perfectly agree with Meffrs. Mylnes in opinion, that they will be attended with all poffible fecurity, as the caufe of failure will then be taken away, that is, the great weight of earth above them, due attention being had to the ftate of the foundation.

7th. The walls of the fouth abutment fo far as they were filled folid with earth, feem to ftand perfectly found and firm, and being of lefs height than the correfpondent ones on the north fide are the lefs in want of help, however for the fake of fecurity, as a further addition of earth will be wanted there, Meffrs. Mylnes in like manner intend to ftrengthen them on both fides with external abutments, which we entirely approve.

We cannot help adding by way of relieving the apprehehenfions that may occur hereafter, that we do not expect thefe or any other methods that can be taken, will put the building in fo equal a poife, but that from the compreffibility of the matter fome joints will appear (efpecially of the upper work) to open, as has happened to all large bridges confifting of feveral arches hitherto built, and probably will happen to all that will be built.

Thus we have endeavoured in the cleareft and moft candid manner we are able, to fet forth the true ftate of this work, as it refpects the contracting parties and the public, and we do not doubt, that notwithftanding the accident that has happened, the reparation will be attended to with fuch diligence and care, that the work itfelf will remain a lafting monument to pofterity.

Edinburgh,
22d *Auguft* 1769.

J. SMEATON.
JOHN ADAM.
JOHN BAXTER.

To the Right Honorable the Lord Provost, Magistrates, and Bridge Committee of Edinburgh.

The REPORT of JOHN SMEATON, Engineer, upon the feveral Matters referred to him by the Minutes of the said Bridge Committee, the 17th January inftant.

HAVING carefully confidered the anonymous plan, together with the feveral matters tranfmitted to me by Mr. Stuart along with the faid minute, I find myfelf at a lofs to come at an accurate judgement upon the whole affair for want of the following materials, videlicet.

A true fection of the ground for the whole length of the bridge from the high ftreet to the oppofite intended landing upon the natural ground.

A copy of the original defign and contract thereupon.

An accurate drawing of what has been really executed in confequence thereof. And

A Report of the condition in which the foundation of the crofs fide walls of the fouth abutment arches, appeared when the rubbifh was removed fo far as to enable Mr. Mylne to build upon them as it is faid; which materials feem neceffary to compare with what is now laid before me. Neverthelefs, that the accomplifhment of this great neceffary work may fuffer no delay from me, from what I have feen and know of the affair, and from what I can collect from the feveral papers tranfmitted to me, I fhall endeavour to deliver myfelf with all the precifion I am able.

Having perufed and re-perufed all the papers above referred to, I find no reafon to deviate in opinion from what is contained in the report of the 22d of Auguft laft, wherein I have the honour to be joined with Meffrs. Adam and Baxter, but find many reafons to confirm me therein, and to more ftrongly enforce the neceffity of the moft material particulars therein contained.

Refpecting the anonymous plan, it feems in many refpects a delineation of what is pointed out in the before mentioned report, which, for the fake of diftinction, I fhall join in calling the Engineers report, the following particulars however excepted.

1ft. He

a center, and as much of the solid work above as this will ſupport, then taking down the abutment wall within two courſes of the baſe, we would lay on two ſtring courſes to be of aiſler within and without and ſtrongly bonded together with chain bars. Upon this as a freſh baſe the abutment wall is again to be raiſed to its proper height, and the arch ſprung over as before, and then finiſhed with an arch of relief as ſuggeſted by Meſſrs. Mylnes. This method to the beſt of our opinion may be put in execution with perfect ſafety to the great arches, yet we cannot take upon us to ſay we can abſolutely enſure it.

6th. Reſpecting the rebuilding of the fallen vaults there is the leaſt difficulty of all, for if the walls of theſe vaults are raiſed ſo high that the crowns thereof do properly clear the road, we perfectly agree with Meſſrs. Mylnes in opinion, that they will be attended with all poſſible ſecurity, as the cauſe of failure will then be taken away, that is, the great weight of earth above them, due attention being had to the ſtate of the foundation.

7th. The walls of the ſouth abutment ſo far as they were filled ſolid with earth, ſeem to ſtand perfectly ſound and firm, and being of leſs height than the correſpondent ones on the north ſide are the leſs in want of help, however for the ſake of ſecurity, as a further addition of earth will be wanted there, Meſſrs. Mylnes in like manner intend to ſtrengthen them on both ſides with external abutments, which we entirely approve.

We cannot help adding by way of relieving the apprehehenſions that may occur hereafter, that we do not expect theſe or any other methods that can be taken, will put the building in ſo equal a poiſe, but that from the compreſſibility of the matter ſome joints will appear (eſpecially of the upper work) to open, as has happened to all large bridges conſiſting of ſeveral arches hitherto built, and probably will happen to all that will be built.

Thus we have endeavoured in the cleareſt and moſt candid manner we are able, to ſet forth the true ſtate of this work, as it reſpects the contracting parties and the public, and we do not doubt, that notwithſtanding the accident that has happened, the reparation will be attended to with ſuch diligence and care, that the work itſelf will remain a laſting monument to poſterity.

Edinburgh,
22d *Auguſt* 1769.

J. SMEATON.
JOHN ADAM.
JOHN BAXTER.

To the Right Honorable the Lord Provost, Magistrates, and Bridge Committee of Edinburgh.

The REPORT of JOHN SMEATON, Engineer, upon the ſeveral Matters referred to him by the Minutes of the ſaid Bridge Committee, the 17th January inſtant.

HAVING carefully conſidered the anonymous plan, together with the ſeveral matters tranſmitted to me by Mr. Stuart along with the ſaid minute, I find myſelf at a loſs to come at an accurate judgement upon the whole affair for want of the following materials, videlicet.

A true ſection of the ground for the whole length of the bridge from the high ſtreet to the oppoſite intended landing upon the natural ground.

A copy of the original deſign and contract thereupon.

An accurate drawing of what has been really executed in conſequence thereof. And

A Report of the condition in which the foundation of the croſs ſide walls of the ſouth abutment arches, appeared when the rubbiſh was removed ſo far as to enable Mr. Mylne to build upon them as it is ſaid; which materials ſeem neceſſary to compare with what is now laid before me. Neverthelefs, that the accompliſhment of this great neceſſary work may ſuffer no delay from me, from what I have ſeen and know of the affair, and from what I can collect from the ſeveral papers tranſmitted to me, I ſhall endeavour to deliver myſelf with all the preciſion I am able.

Having peruſed and re-peruſed all the papers above referred to, I find no reaſon to deviate in opinion from what is contained in the report of the 22d of Auguſt laſt, wherein I have the honour to be joined with Meſſrs. Adam and Baxter, but find many reaſons to confirm me therein, and to more ſtrongly enforce the neceſſity of the moſt material particulars therein contained.

Reſpecting the anonymous plan, it ſeems in many reſpects a delineation of what is pointed out in the before mentioned report, which, for the ſake of diſtinction, I ſhall join in calling the Engineers report, the following particulars however excepted.

1ſt. He

1ſt. He propoſes to build a diviſion wall and to lay floors in the ſouth abutment by way of tying the croſs and ſide walls together, and to take down the north abutment, in order to rebuild it upon the ſame plan as the ſouth.

2dly. He propoſes to raiſe the building four feet higher than it was laid out for at the time of the accident, to fill up this ſpace with earth or rubbiſh, and reduce this additional load by conſtructing hollow cylinders over the piers, which from the draft appear to be intended twenty feet diameter.

In regard to the matter contained in the firſt article, as the anonymous gentleman pretty ſtrongly inſinuates, that the public will not be ſatisfied with the judgment of thoſe who have ſpent a great part of their lives in the ſtudy of the poiſe and ſtrength of materials; as I expect the gentleman knows their mind, I hope they will be ſatisfied with what he has now propoſed, and as Mr. Mylne makes no objection to the execution thereof, I ſhall not object it, as it can do no harm. I only deſire to ſay, that I think it unneceſſary, eſpecially in works to be carried up anew. Had he propoſed to have run a diviſion wall through the north abutment, and to have only taken down the walls below the ſpring of the preſent arches, in order to have tied them afreſh together by good bond ſtones, and then to raiſe them high enough to turn freſh arches at a proper height, inſtead of turning freſh ones over the preſent as propoſed by the engineers, he would have made a judicious improvement; to take them down to the ground can do no more, and to take them up entirely, after having been compreſſed with double the weight they will again be ſubject to, in order to lay them on new bearings, may render them obnoxious to cracks and ſets as before.

To what is contained in the ſecond article, namely, the raiſing the whole building four feet higher, I entirely object: for though this in his opinion may relieve the fears of the public, it will greatly increaſe mine.

From what appeared on view, it was my opinion, and ſeemed that of the gentlemen with me, that the piers of the great arches had complained of the load of earth that then had been upon them, but not in ſuch a degree as to be abſolutely unſafe, and therefore could they be lightened there could be no danger of their failing. What Meſſrs. Mylnes propoſed concerning the ſhaving of two feet from the whole ſurface, might poſſibly be underſtood in different ſenſes by the gentlemen to whom delivered; and though we concurred in the ſame words, it is poſſible we might have different ideas affixed thereto, (ſuch is the ſtate of manhood); I did not for my part underſtand that Meſſrs. Mylnes propoſed to ſhave off two feet from the body of the earth then upon the bridge, which if I

remember

remember right, was about that quantity below the height, which would have been neceſſary to have completed his then plan; but to ſhave off two feet from the plan as propoſed in its completion; for had I underſtood that he meant to reduce the earth upon the bridge, then two feet too low, to be two feet lower, the relative heights of the parapets and declivity would have been four feet, and not two feet greater as obſerved in the report. In ſhort, my opinion, and I underſtood that of thoſe with me was, "that the piers of the great arches could not ſafely carry a greater load than then lay upon them, and with ſome reduction would be ſafe; with this view the 4th article was drawn up, which I deſire in this place may be read.

It is ſaid in remarks upon the anonymous plan, article 5th, that by Mr. Mylne's plan, the top of the cornice or level of the cauſeway, was to be nine feet above the ſoffit of the arches. The ground was then, or was to be, reduced by ſhaving to ſeven feet above the ſoffits; the anonymous plan adds to Mr. Mylne's plan four feet, that is 13 feet above the ſoffits, and is ſo delineated in the plan before me; conſequently the anonymous plan propoſed to lay upon the bridge ſix feet additional height and weight more than was thought prudent by the engineers' report, amounting to upwards of 4000 tons, upon the baſes of the four detached piers, and I beg leave to obſerve, that 20 feet cylinders, or the value thereof, are practicable over the piers, when the road is at the height of ſeven feet above the ſoffits, this 4000 tons is all ſheer addition to the engineers' plan; ſome ſmall deductions for the different height of the parapets above the road excepted.

In order to be more diſtinct upon this ſubject, we will conſider the difference that will ariſe to one pier alone, ſuppoſing one of the piers ſupporting the centre arches, which will be ſubjected to the greateſt preſſure; it is evident, that one of the piers ſupports not only the matter above it, but one half of each adjoining arch, and the matter above them. Six feet addition will therefore lay on a load of 1200 tons upon the baſe of one of the centre piers more than by the engineers' plan, and 600 tons more than they have yet been loaded with, even after deducting the cylinders propoſed; and 350 tons more after deducting the greateſt cylinders practicable in the given dimentions: but without purſuing the anonymous plan any further, I will now take it up as acceded to by Mr. Mylne, and ſuppoſe it to be executed to the greateſt advantage. Now according to the reduction propoſed by Mr. Mylne, there ſtill will be an addition of four feet to the engineers' plan, and though that height will yet admit of cylinders larger in diameter by two feet than marked out in the anonymous plan, yet the load on one of theſe piers will ſtill be greater by 684 tons than by the engineers' plan, and greater by 86 tons than it ever yet has carried, that is, ſuppoſing the ground never made up within two feet of the top of the cornice. The

bridge

bridge committee may, if they pleaſe, try this experiment; and I won't ſay it will not ſucceed; but I can by no means recommend it.

It remains therefore to point out how the bridge is to be made acceſſible in the moſt eaſy manner that preſent circumſtances will allow, conſiſtently with the reductions propoſed in the report of the engineers.

From the eighth article of the explanation of the anonymous plan, it is ſaid, *the building is raiſed four feet higher to make the line of declivity one in* 16, *as was originally intended, and to end at the breaſt of the ſouth abutment*; but the plan before me makes a declivity of about 1 in $14\frac{1}{2}$, and the remarker, article five, obſerves, that to recover the loſt height will require a riſe of ſix feet ten inches; taking this for granted it follows, that at the height aſſigned by the engineers there will be a loſs of eight feet ten inches; now I find the length of the ſlope contained within the compaſs of the plan before me is about 360 feet, and from the tendency of the lines there ſeems to be about 106 feet wanting of the ſummit in the high ſtreet to complete the whole length: it will follow therefore that this addition of eight feet ten inches will reduce the ſlope from 1 in 16 to 1 in 12; and I beg leave to obſerve that in hilly countries, where the ſlopes in turnpike roads can be reduced ſo as not to exceed 1 in 12, they are eſteemed fully to anſwer the intentions. The aſcent of the arches over Weſtminſter Bridge was originally laid out to be 1 in 20, but I apprehend from the eye, that the aſcents at each end, are at leaſt 1 in 12, and it is a kind of rule in theſe parts that in laying out roads and bridges, if the aſcents do not exceed three inches per yard, they are no ways objectionable. The ſlope by me originally laid out for the aſcent of the weſt abutment of the bridge at Perth, is 1 in 12, and of this may be produced a multitude of examples. In fact, ſince the whole aſcent between two given points muſt always remain the ſame, where the length of the declivity happens to be ſuch, that horſes in carriages cannot conveniently trot up, they may as well be reduced to 1 in 12, at which aſcent they can conveniently walk and draw, becauſe the length is leſs than if more ſloping.

If the declivity marked out in the plan before me is to be adopted, then by extending the ſlope a little beyond the middle of the firſt great arch, this ſlope will cut the level marked out in the engineers' report; and to reconcile theſe two planes without ſo great a difference in the height of the parapets, as would be the caſe if the top of the parapets preſerves it level to the ſouth abutment, I would make no ſcruple (were the caſe my own, and I were left to do what I pleaſed) to make the parapet conform to the road; but yet, I would not ſuffer them to meet in an angle, but reconcile them by a curve, ſo that the maſonry ſhould

ſhould ſeem gradually to conform itſelf to the ground it ſtands upon, and to that to which it is to be connected. The line of the top of the parapet is, according to this idea, marked out with red ink upon the plan *; the height of the road being alſo diſtinguiſhed by a dotted line, either of the above methods, as they leave the *ſtability* of the bridge *without a doubt*, I think far preferable to any increaſe of its load, which in raiſing it can ſcarcely be avoided; ſo far from it, I would ſooner propoſe to reduce it two feet more, that is to five feet thickneſs from the ſoffit of the arch to the top of the road; for, as I underſtand the penſtones are from three feet high, there will ſtill be a two feet cover, which, in my opinion, is amply ſufficient, and even then, the ſlope from the ſouth abutment will meet the horizontal plane before you are over the neareſt pier of the center arch, and this plane will ſtill be higher, though not much above the level of the point from whence the north abutment commences; and in my opinion the reducing the whole to one level after the firſt deſcent will have a better effect upon the eye than by a ſecond angle bent the contrary way, in leaving the breaſt-wall of the north abutment, and will at the ſame time greatly relieve the vaults and retaining walls thereof.

I beg leave further to add, reſpecting the fractured arch on the ſouth ſide, that I have no reaſon to differ from what is contained in the fifth article of the engineers' report. I think it may be repaired as Meſſrs. Mylnes have propoſed, and I think it may be taken down and rebuilt with ſafety, and this I adviſe. I think the abutment wall may be effectually tied together, if taken down within two courſes of the baſe, and that the preference of taking it down to the ſurface of the baſe can amount to little more in reality than taking away the remaining *appearance* of a crack, as the foundation will then remain fractured as it is, nor do I think it any ways eligible to take it quite up, for ſince the preſſure it has had has undoubtedly brought all to a ſolid bearing, the taking it up and laying it upon new bearings, may produce greater derangements than it is intended to cure; laſtly, I don't think the method of ſhoaring the great arches propoſed, by timbers to be laid horizontally, is ſo efficacious againſt a ſett of the great arch as the ſhoars recommended in the engineers' report. At the ſame time it is my opinion that either will do, and that neither is abſolutely neceſſary: my reaſons for them were rather to make that ſure, which might eaſily be done, and to relieve the apprehenſions of Meſſrs. Mylnes and the public, than any abſolute neceſſity: on the contrary, I am of opinion, that the great arches would ſtand upon their own legs, *if unloaded of the earth upon them*: but as there is no neceſſity to run this riſque, I do not adviſe the experiment to be tried.

J. SMEATON.

Auſthorpe,
27th *January* 1770.

* This plan is not among the papers of Mr. Smeaton. Ed.

EDINBURGH WATER SERVICE.

The REPORT of JOHN SMEATON, Engineer, upon the State and Improvement of the Water Service of the City of Edinburgh.

THE ſupply of the city of Edinburgh with a ſufficiency of good water being a matter of very great concern, and the Town Council of the ſaid City having done me the honour to conſult me upon the propoſed improvements relative to this buſineſs, when I was laſt at Edinburgh, in the month of September, I have been ſolicitous that no inveſtigation or enquiry ſhould be neglected that might contribute to the perfection and certainty of this great object; and this I was the more induced to do, finding that Baillie Cleghorn, who attended my viewing of the premiſes, had taken this matter very properly up, and needed only that kind of information which might be expected from me profeſſionally, and which my particular ſtudy and application to this branch of hydraulicks, I truſt, enable me to furniſh.

Since the view above mentioned, which was upon the 6th of September laſt, I have received from him not only copies of the two memorials delivered by him to the Town Council, and of the regiſter from April 1778 to March 1779 incluſive, and of the neceſſary printed papers, but alſo a plan and ſection of the Hareburn and Swanſtone pipe from the ſpring to the Comiſtone reſervoir, which I ſuggeſted as neceſſary to be taken, in order to come at proper data for the calculation of what may and ought to be done there; ſo that the matter being now fully before me, I ſhall do myſelf the honour of laying before the Town Council the reſult of my calculations and animadverſions on this occaſion.

It is to be obſerved, that a deficiency of water in the city of Edinburgh ariſes from two cauſes, firſt, from a failure of ſprings collected into the reſervoir at Comingſton, in the dry months of the year, and, ſecondly, from an incapacity of the main pipe of conduct, which conveys it from thence to the town's reſervoir on the Caſtle Hill, to bring a ſufficiency to anſwer the demands of the increaſed number of houſes and inhabitants, who are generally wanting the winter ſeaſon, when there is the greateſt plenty at Comiſtone, if the pipe would but bring it. Doubtleſs, the firſt and moſt obvious expedient would be that of enlarging the main pipe; but this being a work of great expenſe and not ſoon effected, Baillie Cleghorn very judiciouſly conſidered that an increaſe of declivity, or total fall between the reſervoirs, by increaſing the velocity of the water's current, would in event bring more water as certainly as an enlargement of the pipe; he therefore propoſed and executed

executed what immediately admitted of being done, that is, to let in the water iſſuing from the main pipe into the reſervoir at Caſtle Hill, at the bottom inſtead of the top, as it uſed to be, by which empty an addition of fall is gained equal to the depth of the reſervoir, which being 7½ feet, this added to 44, the total fall or difference of level between the two reſervoirs (in a length of 2½ miles), making together 51¼ feet, inſtead of 44, has ſo far increaſed its velocity, when there is little water in, there is little water in the Caſtle Hill reſervoir, and when it is moſt wanted by the town, that as it appears by the regiſter it is now capable of diſcharging 200 pints per minute, inſtead of 160, a difference equal to one full fourth of its former produce, and amounting to the additional quantity of 112 tons per day, which alone is a very valuable acquiſition.

Obſerving the good effects of this alteration, he has propoſed by way of ſtill further increaſing the quantity of water to be brought by the ſame pipe without enlargement of its dimenſions, to conſtruct a new reſervoir in the garden of Heriot Hoſpital, which being upon a level with the ſtreet of the Trone church, is conſequently above the greateſt part of the city, new town, and ſuburbs of Edinburgh, at the ſame time that it is 119 feet below the level of the reſervoir at Comiſtone, inſtead of 51¼, which is the preſent greateſt fall to the Caſtle Hill reſervoir; conſequently if thoſe parts of the town that cannot be commanded by the lower reſervoir, are continued to be ſerved from the Caſtle Hill, a part of the 24 hours may be appropriated to collect water in the Caſtle Hill reſervoir, ſufficient for 24 hours ſupply for that part of the town, that diſtrict being ſtill dependent on that ſource, and a much greater portion of the 24 hours can then be applied to collect water into the new reſervoir, which, from the greater fall, will be delivered at a much greater rate, and much more water will be brought for the 24 hours ſupply of the reſt of the town, than if it were all obliged to aſcend to the Caſtle Hill reſervoir; this he has proved experimentally by obſerving that the diſcharge of water at the cleanſing cock in the graſs market, lying 170 feet below the level of Comiſtone reſervoir, was 160 pints per minute more than would have been diſcharged at the Caſtle Hill reſervoir, though the orifice by which it was diſcharged was much leſs than the bore of the pipe, and he alſo further confirmed this, by trying the diſcharge at the ſecond cleanſing, each above a mile from Comiſtone, which though only 131 feet below the level of the ſaid reſervoir, yet diſcharged 200 pints per minute more that could be diſcharged at the Caſtle Hill, and it is to be preſumed, that this cock alſo was leſs than the bore of the main pipe.

This propoſition for a new reſervoir at Heriot's Hoſpital, however judicious and effectual for bringing an additional quantity of water from Comiſtone when there is a ſurpluſage there, yet when from the other cauſe, a failure of the ſprings, there is not more water than the preſent capacity of the pipe will convey, no more can be had; and though this chiefly

chiefly happens (as appears from the regifter) in the months of Auguft, September, and October, when moft families are out of town, yet as the prefent furplufage in May, June, and July does not appear confiderable, in every event an additional fupply at all times is a thing moft defirable; and this Baillie Cleghorn has not only in part done, by opening fprings and preventing unneceffary waftes before the arrival of the water from the feveral fources at Comiftone; but having obferved that a confiderable quantity of water furnifhed by the Hareburn runs continually wafte that cannot be received into the Swanftone pipe, and thereby conveyed to Comiftone, which the 12th of Auguft laft, in a dry feafon, amounted to no lefs than 160 pints per minute more than was received into the pipe, has propofed to lay a new pipe, of a fufficient bore to convey the whole water of this burn in dry feafons as above, which he propofes to be of four inches, in aid of the other, and to avoid an overload of expenfe, he propofes it to be of wood.

Thefe, I think, are the propofitions laid before me. On viewing the premifes I obferved that the whole of the Hareburn might be taken up upon confiderably higher ground than the Swanftone well, where it is now taken in; and being informed that the water furnifhed by the Swanftone fpring itfelf is but an inconfiderable part of the water now conveyed by the Swanftone pipe, (which, at the utmoft, appears from the regifter to be 76 pints per minute) it occurred to me that it might poffibly come out from a proper calculation, that by lengthening the Swanftone pipe to the rife fo as to take in the water of the Hareburn with that of the next fpring above, would add fo much to the fall (leaving out the Swanftone fpring, as inconfiderable in proportion to the acquifition of the Hareburn) that the prefent pipe might then be able to convey the whole of the Hareburn water; but this could only be known by a furvey of the length and profile, fhewing the difference of level that there now is and may be further obtained in the courfe of this pipe. From the furvey and level now before me, it appears that the fall in the pipe itfelf is much greater, and the additional fall to be gained to the next fpring above much lefs than I expected; I fhall therefore infert the following table, fhewing the refult of the different calculations I have made, checqued with the water actually given in pints per minute, where opportunity has offered; from whence may be inferred what degree of aid it is to be given to thofe where that opportunity has not offered.

For in the prefent length of the Swanftone pipe, viz. 2145 yards, there is no lefs than 168 feet of fall; and to get 40 feet of fall in addition we muft increafe the length 280 yards more, which, though giving upon the whole a greater power, yet is not fufficient increafe to carry the neceffary addition of the Hareburn water.

TABLE

TABLE of RESULTS of WATER given and expected by Calculation on different WATER-PIPES belonging to the City of *Edinburgh*.

No	Pipe calculated upon.	Bore	Length in Feet.	Fall in Feet.	Water expended by calculation.	Water given by Meafure	Difference.	Proportional Difference.
1.	Swanftone pipe as it now lies - -	$2\frac{1}{2}$	6435	168	116	76	40	$\frac{1}{3}$
2.	Do. with 280 yards to the fpring above, and 40 feet additional rife - -	—	7275	208	122	—	—	—
3.	For the firft 1000 yards, in which is a fall of 30 feet - - -	—	3000	30	72	—	—	—
4	Do. for the principal defcent, exclufive of the firft 1000 yards from the Swanftone well -	—	3435	138	145	—	—	—
5.	A new pipe to convey the water from the prefent Swanftone well to Comiftone refervoir -	—	6435	168	236	—	—	—
6.	The main pipe from Comiftone to the Caftle Hill, before the alteration - - -	$4\frac{1}{2}$	14637	44	159	160	1	$\frac{1}{159}$
7.	Do. after the alteration - - -	—	—	$51\frac{1}{2}$	173	200	27	$\frac{1}{6}$
8.	The main pipe water drawn at the Grafs-market cleanfing cock - - -	—	13985	$170\frac{1}{2}$	346	360	14	$\frac{1}{24}$
9.	The main pipe water drawn at the fecond cleanfing cock - - -	—	5359	131	492	400	92	$\frac{1}{5}$
10.	The main pipe water drawn at a refervoir in Heriot's Hofpital garden - -	—	13550	110	280	—	—	—

The deficiency of No. 9. in giving $\frac{1}{5}$ lefs than it ought to have done by calculation was, doubtlefs, owing to the bore of the cock not being large enough to let the water freely out, and it may be inferred in refpect to No. 8. that it was fufficiently large; but in regard to No. 1. it appears that the Swanftone pipe is confiderably defective in giving its proper quantity, which may arife from an injudicious ufe of its air-cocks, or their not being air-tight when clofed, or from the pipe itfelf not being air-tight; for if any of the cocks are fuppofed to be open, or to take in air as much as the pipe will want, then it appears from No. 3. that the Swanftone pipe gives as much water as by calculation under thefe circumftances it ought to do, or the deficiency may arife from its not being fully $2\frac{1}{2}$ inches as reported, for if really only $2\frac{1}{4}$ it gives nearly its proper quantity. It does not however appear, that, if rendered perfect, it is likely to convey the waters of Swanftone fpring and Hareburn, viz. 76 pints per minute that it now brings, together with 160 pints in addition, in the whole 236 pints, but it appears from No. 4. that a pipe of $3\frac{1}{2}$ inches bore would fully anfwer the end.

Doubtlefs a wooden pipe of four inches in aid of the prefent would be more than enough, nor can there be any fufficient objection to the ufe thereof; but as all the reft of the water-

water-pipes belonging to this work are of lead, which for this purpofe is not only the fweeteft but moft durable, it appears to me likely that if the prefent $2\frac{1}{2}$ pipe be taken up and recaft of $3\frac{1}{2}$ inches, the addition of labour and weight of lead may be done for nearly the fame expenfe as the laying a wooden pipe.

The weight of a molded pipe of $2\frac{1}{2}$ inches bore is feldom lefs than 30lb. to the yard, or more than 36; in the prefent cafe I fuppofe the medium weight, 33lb. per yard; this, for the length of 2145 yards, will amount to 622 cwt.

It appears from Mr. Leflie's fection, that this pipe is almoft upon a continual defcent, there being no rife but from a point which is 581 yards from the fpring head to another at a thoufand; in which fpace the pipe rifes 26 feet perpendicular, fo that the pipe being conftantly open at both ends this is the only part that fuftains the preffure of a perpendicular column; for were the pipe laid upon one continual defcent, and both ends open, the water would lay no ftrain upon it, but run through it merely as it would through an open channel, and the preffure of 26 feet that particular part fuftains is fo inconfiderable that it may be laid out of the queftion, as it will be neceffary to make the pipe ftronger merely to preferve its figure from being preffed inwards than would be neceffary to fuftain the column of water tending to prefs it outwards.

The cafe of the main pipe to the Caftle Hill is very different, for it appears from the general fection, that from the Grafs Market cleanfing-cock to the top of the Caftle Hill refervoir, whither it ufed to rife, is an afcent of $126\frac{1}{2}$ feet, and fo much preffure of perpendicular column of water, that part of the pipe muft fuffer in croffing the bottom of the Grafs Market.

For thefe reafons, the Swanftone pipe needs no other ftrength than what will be prudent to give it, to preferve its figure againft the preffure of the earth, the accidental croffing of carriages, together with plows and animals over the ground; and for thefe purpofes I look upon a $3\frac{1}{2}$ inch pipe as fufficiently guarded (it being carefully bedded and covered) if made of fheet lead turned and burnt, of the ftrength of 11lb. to the fquare foot, which is exactly $\frac{3}{16}$ of an inch in thicknefs, which method I alfo look upon as more fafe from leakings than molded pipe.

A pipe of this conftruction will contain a foot fuperficies in a foot running, fo that it will be the fame weight as it is computed the prefent pipe is of, viz. 33lb. to the yard, fo that the prefent pipe recaft will make the new one, with the addition of fo much lead as will make good the wafte: and from a careful eftimate, I find, that this pipe fhould be

8 recaft,

recaft, the wafte made good, carriage to Edinburgh and out again included, for 3s. 9d. per yard, which, for 2,145 yards, amounts to the fum of 402l. 3s. 9d., whereas by a fimilar eftimate I find, that an elm pipe of four inches bore, including carriage out, the fum of 360l. 11s. 3d. exclufive of the expenfe of opening and filling the ground, which I fuppofe to be nearly equal in both the cafes; the difference, therefore, being no more than 41l. 12s. 6d. I apprehend will not be an object in the determination, and in cafe the recafting of the lead pipe is determined upon, I fhall be ready to fupply fuch further directions for the cafting and laying of it, as fhall enable it to produce the whole of the effect expected from it.

We come now to the propofition that relates to the erection of a refervoir in Heriot's Hofpital Garden; and to give it fome elevation and advantage, I have fuppofed it to be elevated nine feet above the ground, that is, the water to come in at 110 feet below the Comiftone refervoir, at which depth may be expected to be got 280 pints per minute, as per No. 10.

It is laid down by Baillie Cleghorn, as a certainty drawn from experience, that when the water comes into the prefent refervoir, at the rate of 200 pints per minute, that this is fufficient to ferve the city of Edinburgh well, that is to fay, 288,000 pints in 24 hours. It muft follow, that 288,000 pints in 24 hours iffued from a refervoir in Heriot's garden, muft ferve every part of the town that can be ferved thereby very well.

Now 288,000 pints coming in at the rate of 280 pints per minute, will be received in 17 hours $8\frac{1}{2}$ minutes, there therefore will remain 6 hours $51\frac{1}{2}$ minutes for the main to run into the Caftle Hill refervoir, which will ftill thereby be capable of ferving nearly upon $\frac{7}{24}$ of the inhabitants as amply as they are now ferved, at the rate of 200 pints per minute. But if $\frac{7}{24}$ of the inhabitants are fupplied from the Caftle Hill refervoir, this will fpare $\frac{7}{24}$ of the water brought daily into the new refervoir, to be diftributed to the fouth fide of the town and extended royalty, beyond what is fuppofed to be comprehended in the fervice of 200 pints per minute.

It therefore now only remains to fix the dimenfions of the new refervoir in Heriot's garden, fo that it may hold a quantity of water equal to the fervice laid down.

I take it for granted, that by far the greateft part of the water ufed in the city of Edinburgh is drawn in the compafs of 14 hours per day, and confequently that this may be looked upon as the average time of the daily expenditure. Now if the water to be drawn from the new refervoir were to come in at the fame rate it is drawn out, no refervoir would

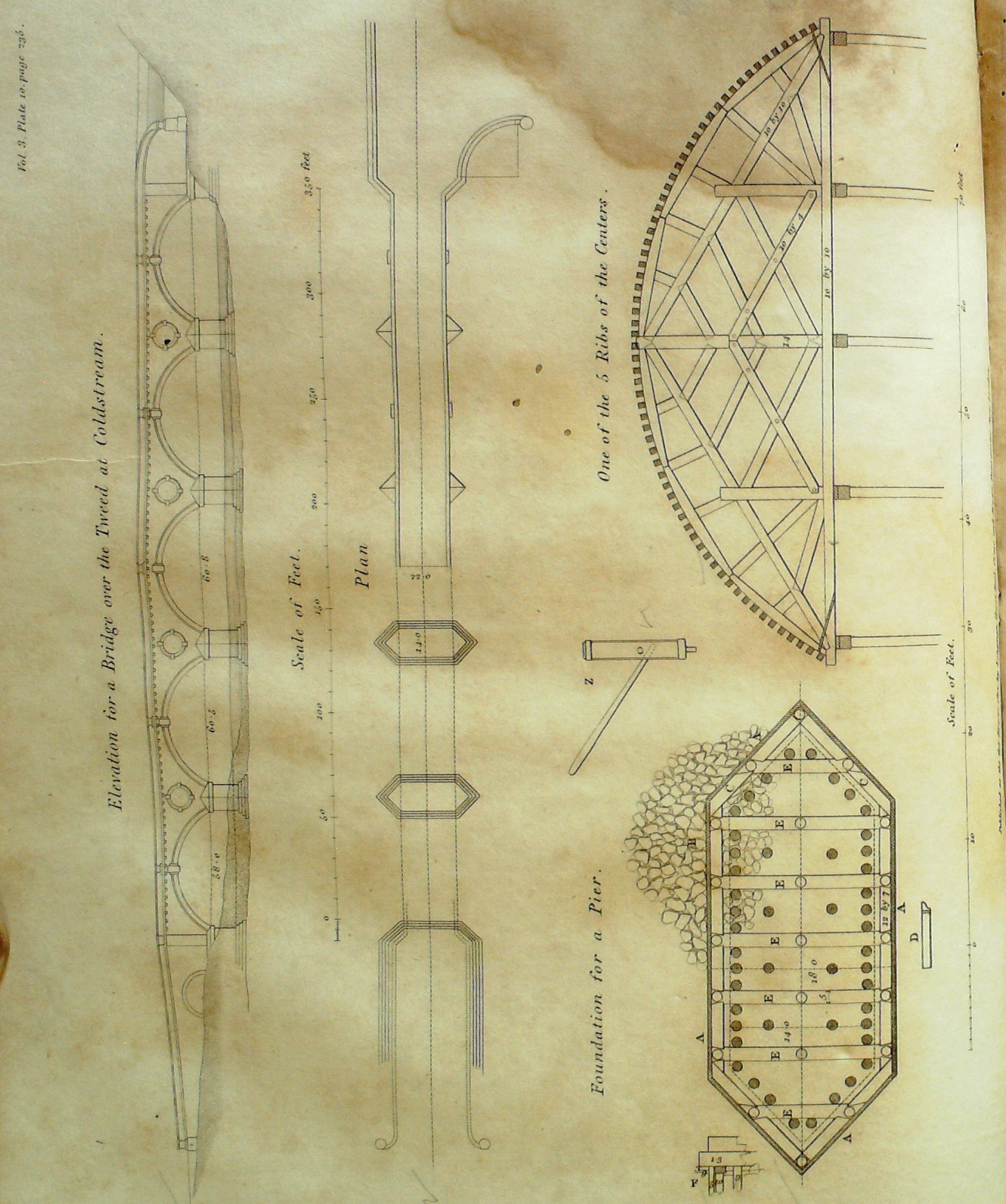
would be neceffary, but only a fmall ciftern to receive it. But if that be taken out in 14 hours, that requires 17 hours $8\frac{1}{2}$ minutes to come in, then there will be required a refervoir capable of holding 3 hours $8\frac{1}{2}$ minutes water to begin with in the morning, fo that after 14 hours draft upon it, the contents of the ciftern, with what comes in during the time, will be ended with the clofe of the fervice each day.

But a refervoir that muft contain 3 hours $8\frac{1}{2}$ minutes water, at the rate of 280 pints per minute, muft contain 52,794 pints, which at $103\frac{4}{10}$ cube inches to the pint, will amount to $3159\frac{1}{10}$, fay 3160 cube feet, and if we fuppofe five feet depth of water to be filled and emptied therefrom, then, if fquare, the fide of the fquare will be 25 feet $1\frac{3}{4}$ inch, or any other equivalent dimenfions, as for inftance, [illegible] by 27, allowance being made in depth, fuppofe half a foot, to prevent its running over the brim, inftead of the wafte pipe, and what may be left at the bottom.

I would, therefore, fuppofe it convenient, according to this eftablifhment, not to difpenfe any water from this refervoir before feven in the morning or after nine at night, but to let the water run from the main into the refervoir till 10 at night, then to turn it upon the Caftle Hill till five o'clock in the morning, when being again drawn into the new refervoir by feven o'clock, it will have got three hours water ready to begin the day's fervice. Experience, however, of the wants of the inhabitants muft ultimately regulate the matter; and though I have fhown that on a fuppofition the wants of the inhabitants, that muft neceffarily be ferved from the Caftle Hill, will be fupplied by feven hours water from the main (but like the other to be diftributed in 14 hours), that a refervoir of the dimenfions given will be fully fufficient; yet there is nothing but the charge to prohibit its being made of any larger fize, that fhall be thought convenient, becaufe that will always be a treafury of water to anfwer any fudden exigence, as in like manner will that at the Caftle Hill, which ought always to be got and kept full whenever the fupply from Comiftone will admit thereof.

J. SMEATON.

Aufthorpe,
12th *February* 1780.



COLDSTREAM BRIDGE.

(See Plate 10.)

To Mr. Pringle.

Sir, Edinburgh, 31ſt July 1763.

This comes to acquaint you, that the Truſtees of Coldſtream Bridge having had a meeting, I laid before them the different plans, with the reaſons thereof, when the low plan * was unanimouſly choſen, as being ſufficiently elegant, and at the ſame time better adapted to the funds, than either of thoſe elevated to a ſemi-circle. According to this plan the ſide arches are 58 feet, and the two adjoining the centre 60 feet 5 inches, and the centre arch 60 feet 8 inches. They are all parts of the ſame circle, and the leaſt arches are one-third, ſo that the others riſe higher, as the additional ſpan admits. The height of the piers above low water, including the impoſt of two feet, is 12 feet preciſely; ſo that the ſhaft of the piers below low water muſt be raiſed 10 feet before the impoſt courſe comes on. I hope I ſhall be able to ſend the deſign for the centre, with the fair plan. I have ſatisfied the gentlemen relative to the foundation and method of proceeding.

Your's, &c.

J. SMEATON.

Mr. Foreman to Mr. Smeaton.

Sir,

I trouble you with this by order of a general meeting held this day for our bridge, who took into conſideration the centre you propoſed for throwing over the arches, and the one you ſaw Mr. Reid have a draft of, and which they had all ſeen before, and which you had no objection to, except that you thought a cheaper one might be made, that would anſwer the purpoſe. But on the wright's (carpenter's) eſtimate of both, yours proves to be the deareſt by about eight pounds. Out of deference to your judgment, they would not, however, fix upon it till they had conſulted you, and therefore ordered me to write to you, ſtating the different eſtimates, and begging to know if the centre propoſed by you is preferable to the other, without regard to the difference of expenſe, for they chooſe to be determined by your opinion.

Your's, &c.

JOHN FOREMAN.

Coldſtream,
March 27, 1764.

* This is the plan here given.

To

To Mr. Foreman.

Aufthorpe, 3d April 1764.

I am obliged by the confidence the truftees are pleafed to honour me with, though in the prefent cafe there was no need for hefitation. The draft Mr. Reid fhewed me being upon the fame principle as the centres whereon the arches of Weftminfter Bridge were turned, there can be no doubt of its anfwering the end propofed, if juftly and properly executed. But as I look upon thofe centres, when originally defigned by the ingenious Mr. King, as intended to let the boats, &c. upon the river pafs under the arches even while they were building, there was a neceffity of making them hollow, and of diftributing the fupporting piles on the fides only; and on this account the middle part being geometrically fupported, induced a neceffity not only of ftronger timbers, but of greater care in framing the bearings thereof, than if each part of the weight were more directly fupported. It therefore occurred to me that when this was the cafe, not only flighter timbers would ferve, but a much more fimple and eafy conftruction. What I had therefore in view was to diftribute the fupporters more equally under the burthen, preferving at the fame time fuch a geometrical connection throughout the whole, that if any one pile, or row of piles, fhould fettle, the incumbent weight would be fupported by the reft.

With refpect to the fcantlings, I did not fo much contrive how to do with the leaft quantity of timber, as how to cut it with the leaft wafte; for as I took it for granted the centre would be conftructed of Eaft Country fir, I have fet down the fcantlings fuch as they ufually are in whole balks, or cut in two lengthways, and as I think the pieces will fuffer lefs by notchings in the middle interfection, and being cut into fmall pieces, it will remain of value for common building, after it has been done with as a centre. If therefore the value of the timber each way, after it has been done with for centres, has been taken into the account, and there ftill remains againft me a balance of eight pounds, or even eight fhillings, I have not that partiality for my own fchemes, to prefer them where they are not applicable. Yet I muft obferve that had I a lefs opinion of your carpenter than I have, I fhould prefer my own for this reafon, that as the conftruction is more obvious, and lefs exactnefs required in the handling, I fhould expect to get a good centre made by fome in this way, that would make but bad work of the other.

Yours, &c.
J. SMEATON.

To Mr. Pringle.

Dear Sir,

Aufthorpe, 27th June 1764.

I am forry to find that the Tweed's gravel lies fo very open; had it been wrecked up with fand and matter, as is moft common, you would have completed the excavations with all eafe and pleafure; but as it is common in water-works for things to turn out contrary to

to expectation, change of circumftances requires change of meafures, and nothing but time and patience can overcome the difficulties that often arife; and you may remember this as an undoubted maxim, that the lefs the bufinefs is put in a hurry, the fooner it will be done, provided the power is fteadily applied towards the end propofed.

Piling foundations is generally a very tedious and expenfive job; I was therefore defirous to avoid it by going down to the rock; but fince the nature of the gravel makes the drainage likely to turn out fo very expenfive, of two evils it is beft to choofe the leaft; I have therefore enclofed a defign for piling the foundation at its prefent depth, viz., as I underftand it, three feet below the bed of the river. It is common in cafes of this kind to lay down a grating and build upon it without any piles at all; and this is certain, that fo long as the matter keeps under the grating undifturbed, nothing bears weight better than gravel; but in fo rapid a river as the Tweed, we are far from fure that the floods may not take away the gravel round the pier, below its prefent furface, and lay the grating bare; in which cafe the matter will move from under it, firft near the fides, and then farther in, fo as to let down the pier, and damage the arches. The common defence is to build ftarlings round the piers, terminating above low water; but as thefe confiderably contract the water way, they are the caufe of its acting more violently upon them towards their deftruction.

In the enclofed defign (fee the plate), the main dependence is upon a fheet of plank piling AAAA, encircling the matter whereupon the pier is built, and which will hold it in, though the external gravel fhould by accident be taken away three feet below the tops thereof, that is, fix feet below the prefent bed of the river; but to prevent this accident, the excavated fpace between the fheet piling and the coffer dam is to be filled with rough rubble-ftone B, as it comes out of the quarry; which, if any accident happens to it, may be repaired by an addition of the fame kind of matter; but which can never happen after it is confolidated by the gravel wafhing into the fame, unlefs the gravel without the boundary thereof fhould happen to be difturbed, and which, if filled even with the bed of the river, by throwing in rubble, will ftir no more in the fame place.

The fheet piling is to be driven as clofe to one another as may be, and the heads fpiked to the frame CCC, and afterwards cut level with the furface thereof; the bottom of the plank piles being canted off as reprefented at D, will keep them clofe at the foot. This kind of plank piling when intended to hold water is grooved or dove-tailed one into another; but as thefe are only intended to retain the gravel, they will do plain, which will fave a good deal of time and labour; for to drive into gravel, they ought to be of double the thicknefs if of fir; or elfe to be made of elm or beech to prevent their fplitting, which laft

last mentioned woods I apprehend your ſituation could not readily afford. The piles repreſented under the frame CCC, are to be firſt drove to the level of the preſent bottom, and cut to a level, and the frame to be faſtened down with pins thereupon. The tye-beams EE, &c. being dove-tailed to the outward frame, are chiefly intended to prevent the frame from flying outward by the preſſure upon the matter within; thoſe beams may be let in the outer frame about $3\frac{1}{2}$ inches; the other piles not repreſented under the frame, are to be drove after the frame is laid, and cut level with the upper ſide of the frame; then the whole of the frame and tye-beams are to be underpinned with rough ſtones; and the reſt of the ſpaces to be rough paved and drove down with a heavy paviour's hammer, to be worked by two men, and the ſpaces filled with gravel; upon this foundation (which will be a kind of artificial rock) you are to build your maſonry, but note, that the outſide ſtones muſt all be headers, and long enough to reach upon the pile heads of the interior row, and alſo to project about nine inches beyond the ſheet piling, and to be let down three inches thereupon, as ſhewn in the little ſketch F, which will prevent the ſpikes from drawing or flying from the frame. In the courſe that brings you above water, you muſt lay in block ſtones in rows agreeably to the tye-beams, and thereby again cramp the work together from ſide to ſide. With reſpect to the interior piles, if care is taken to lay a ſound ſtone upon each pile head, this will anſwer better than planking; becauſe it gives leave for every part of the work to be brought into contact upon the paving; ſo that the matter of every part of the area will come to an equal bearing, and ſave expenſe. This method being carefully and judiciouſly executed, will I think be little inferior to a foundation upon the rock itſelf, eſpecially if the whole has ſufficient time to ſettle before the arches are turned.

As your large piling engine will, I fear, be too heavy and cumberſome for this job, I would adviſe you to get two light ones made in the cat's-tail way, to be worked with 10 or 12 men each; the ſcantling of the ſtuff need not be above $3\frac{1}{2}$ inches, ſo that the men that work it, will eaſily move it; three, $3\frac{1}{2}$, or at moſt 4, cube feet of timber, will make as large a ram as thoſe men can work, but it had better be under than over-weight; it is probable that the piles will require no ſhoes, or if they do, the bearing piles being ſharpened to a flattiſh point about two inches broad, and covered with a piece of rolled metal, ſuch as is made for caſk hoops, turned up and nailed on each ſide like a ſaddle, and a broader one of milled iron plate put on in the ſame way upon the plank piles, is the whole we have uſed in the many thouſand piles we have drove upon the Calder, which is in general a hard gravel mixed with ſtones. I would not adviſe you to drive longer than while you find the piles have got a firm ſeat upon the rock, leſt by too much driving you cripple them, and render them uſeleſs.

The

The piles repreſented to be under the frame and tye-beams may be got near enough their places, by lines ſtretched from fixed points upon the coffer dam, without taking off the water; and may be driven down below the water's ſurface by ſetts, made as ſhewn at Z in the plate, the little iron pin at the bottom going into a hole in the pile head will keep it ſteady thereupon; the upper end ſhould be convex, and the lower concave, to prevent ſplitting the pile, and two handles ſtanding at right angles to each other will be better than one, as two men will thereby keep it more ſteady than one. This done, the water muſt be pumped out while they level the pile heads, and lay down the frame; then the reſt of the piles may be drove by the ſide of the frame, by ſets as before; a little practice will render the whole eaſy; laſtly, the water muſt be pumped out while the pile heads are levelled, the underpinning and paving is performed, and the pier brought above water; the ſtones being all ready prepared and got as convenient to the place as poſſible in the mean time; as to the rubbling on the outſide, it may be thrown in at convenience, as well when the water is in as out; but muſt be done before the coffer dam is removed. I would adviſe to throw into the water for about 30 feet round the coffer dam, a light ſprinkling of corn mould earth, this may poſſibly choak up the pores of the gravel, and eaſe you of part of the water; as much as will amount to three fourths of an inch thick, will be ſufficient.

If you will pleaſe to let me know whether the rock be of ſuch a nature that the piles may be driven five or ſix inches therein, I can contrive you an eaſier way of laying the next pier.

I am, Sir, your moſt humble ſervant,

J. SMEATON.

P. S. The piles that are repreſented round, need not be made ſo if your ſtuff is ſquare; if you have not a ſufficiency of ſtone for the outſide of the firſt courſe, as above directed, you may interſperſe headers and ſtretchers, but the more headers the better.

Auſthorpe, 27th May 1765.

To Mr. Reid.

The making of a deſign for the caiſſon has not yet come into the courſe of buſineſs: however, that you may be proceeding to get proper ſtuff, as many two and a half inch deals as will reach round the baſe of the caiſſon by the ſum of their breadth, and whoſe length is one foot more than the common depth of the water in the place where it is to be uſed, will make the covering of the ſides; and ſo much Riga balk as reduced into three inch planks when laid croſs and croſs, ſo as to form a ſolid bottom of ſix inches thick, about one foot on every ſide larger than the baſe of the pier, will form the bottom of the caiſſon: other timber for braces, &c. will be wanted.

I am

laſt mentioned woods I apprehend your ſituation could not readily afford. The piles repreſented under the frame CCC, are to be firſt drove to the level of the preſent bottom, and cut to a level, and the frame to be faſtened down with pins thereupon. The tye-beams EE, &c. being dove-tailed to the outward frame, are chiefly intended to prevent the frame from flying outward by the preſſure upon the matter within; thoſe beams may be let in the outer frame about $3\frac{1}{2}$ inches; the other piles not repreſented under the frame, are to be drove after the frame is laid, and cut level with the upper ſide of the frame; then the whole of the frame and tye-beams are to be underpinned with rough ſtones; and the reſt of the ſpaces to be rough paved and drove down with a heavy paviour's hammer, to be worked by two men, and the ſpaces filled with gravel; upon this foundation (which will be a kind of artificial rock) you are to build your maſonry, but note, that the outſide ſtones muſt all be headers, and long enough to reach upon the pile heads of the interior row, and alſo to project about nine inches beyond the ſheet piling, and to be let down three inches thereupon, as ſhewn in the little ſketch F, which will prevent the ſpikes from drawing or flying from the frame. In the courſe that brings you above water, you muſt lay in block ſtones in rows agreeably to the tye-beams, and thereby again cramp the work together from ſide to ſide. With reſpect to the interior piles, if care is taken to lay a ſound ſtone upon each pile head, this will anſwer better than planking; becauſe it gives leave for every part of the work to be brought into contact upon the paving; ſo that the matter of every part of the area will come to an equal bearing, and ſave expenſe. This method being carefully and judiciouſly executed, will I think be little inferior to a foundation upon the rock itſelf, eſpecially if the whole has ſufficient time to ſettle before the arches are turned.

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Auſthorpe, 27th May 1765.

To Mr. Reid.

The making of a deſign for the caiſſon has not yet come into the courſe of buſineſs: however, that you may be proceeding to get proper ſtuff, as many two and a half inch deals as will reach round the baſe of the caiſſon by the ſum of their breadth, and whoſe length is one foot more than the common depth of the water in the place where it is to be uſed, will make the covering of the ſides; and ſo much Riga balk as reduced into three inch planks when laid croſs and croſs, ſo as to form a ſolid bottom of ſix inches thick, about one foot on every ſide larger than the baſe of the pier, will form the bottom of the caiſſon: other timber for braces, &c. will be wanted.

I am

I am much furprifed at your account of the water rifing three feet perpendicular on the weft fide of the bridge, more than on the eaft in time of floods, and think you muft have made fome miftake; but if the cafe be as you ftate, it will be highly neceffary to take away the ground, and make a clear paffage through the firft arch, as well as to remove all the gravel thrown out of the foundation, and every other impediment to the free paffage of the water: and alfo carefully to examine from time to time whether the rubble at the foot of the piled piers keeps its place without derangement; if not, timely to renew the fame with heavier ftones, or by extending the quantity. But I do not apprehend this need be done till you find fome call for it.

Your's, &c.
J. SMEATON.

From Mr. Pringle. Lees, November 22, 1766.

The Truftees for Coldftream Bridge hearing that you have infpected it very narrowly, beg you will be fo good as to let them have your opinion of it in writing; particularly if you are perfectly fatisfied about the fufficiency of the work, and if you think it has been carried on with proper expedition and economy.

Do you approve of laying a gangway on each fide for foot paffengers? And is there gravel enough laid on for this winter, to protect the crown of the arches from the weight of any carriage whatever?

Your's, &c.
J. PRINGLE.

To Mr. Pringle.

Dear Sir,

Your favour of the 22d came to me at a time when I was fo much engaged (and which has indeed been the cafe ever fince I had the pleafure of feeing you at Coldftream), that I could not poffibly give you a diftinct anfwer to your queftions concerning Coldftream Bridge fooner than the prefent; for of all things I cannot make time.

1ft. As to the fufficiency of the work? In anfwer to this I can fay with great pleafure and truth that I have not feen better, and in this refpect I fhould have thought myfelf very happy if every defign of mine had received equal juftice in the execution; nor can I apprehend that any material part will be fubject to failure in a very long courfe of years, provided that a little attention be paid to the two piers, that are founded on piles; to fee that the furrounding rubble ftones lie in their places; or if removed by the great rapidity of floods, to be replaced by others as foon as may be; it will be neceffary to attend

attend to this point for fome years, though it is what moft probably may not ever happen; there being all the fecurity in the cafe that can be.

2dly. As to the length of time? According to the account I have received, it was begun the 7th July, 1763, and opened for all kinds of carriages the 28th October, 1766. A fpace of time comprehending three years three months and three weeks. This bridge confifts of five principal arches, which with the four intermediate piers extend 353½ feet between the abutments; befides two abutment arches of 20 feet each; and including abutments, extends 568 feet in the whole, being in breadth, including parapets, 25 feet. I doubt not but a much greater quantity of ftones may be put together in the fame time upon the dry land, or in a fituation not expofed to fo many hazards: but it is confidered that the River Tweed fwells by rains and fnows frequently 14 feet perpendicular, and comes down with great rapidity; fo that the work could not be purfued with any tolerable profpect of fafety more than fix months in the year, and thofe frequently interrupted by fudden land floods as aforefaid; thefe things confidered, I do not know whether there is any example of fo great a work attended with the fame difficulties that has been done in fo fmall a time.

3dly. Refpecting the economy that has been obferved in the conftruction thereof, I think you informed me that the neat expenfe of building this bridge did not or would not when fully completed exceed 6000l. Things of this kind are beft judged of by comparifon; we have feen inftances of bridges as long, as broad, and as high-built for a lefs fum; but either they have been built in a more gentle river, or their piers have not been laid fo deep below the low water furface, or below the bed of the river; or they have been laid upon a more uniform ftratum of matter, or lefs fcrupuloufly fecured, or they have been built with fmaller ftones, or lefs exactly put together; fo that taking in the whole I believe there has been no example of any bridge being built for fo fmall a fum where circumftances have been equal or fimilar: and it is much to the credit of Mr. Reid, the furveyor of this work, that every thing that has been tried has fucceeded; and the whole has been done without lofs of life or limb to any one concerned: nor does there appear any fettlement, falfe bearing, or fiffure in the whole work, fave a very minute one but juft difcoverable in the common fpandrell walling above one of the piers, or one fide, and in the joining of the work of two different years, and this wholly occafioned by laying a weight of gravel in the fpandrells of the arches that reft on this pier when none could be laid in an adjacent fpandrell to balance it; the whole not worthy of mention, but to fatisfy thofe who may have thought it of more importance than it really is.

So much as to the ſufficiency of the work and the conduct thereof: you next enquire, Whether there is a ſufficiency of gravel to protect the crown of the arches during this winter from the weight of any carriages whatever? I am told there is 18 inches thick above the crowns of the arches, and if ſo it is very ſufficient; if it ſhould happen to cut deep, which is not to be expected, the rutts ſhould be occaſionally filled: and I apprehend it would do very well if never filled higher; but for greater ſecurity it will be proper to make an addition as hereafter mentioned.

Laſtly, You aſk me if I approve of laying a gangway on each ſide for foot paſſengers? I think it will be very proper to cover the ſpandrell walls with tolerably thick ſcapelled flags or paving ſtones, which will not only be a caping for the ſpandrell walls, and thereby prevent the wet from ſoaking down into them, but at the ſame time make a walking path on each ſide, and as there will ſtill be 16 or 17 feet clear, this will be very ſufficient for the meeting of carriages: the gravel then may be made up within nine inches of the ſurface of the walking paths, and laid a little rounding in the middle like a turnpike road. N. B. It will be proper to lay a ribband of ſtone nine inches thick next the road, to prevent the grazing of the wheels, or elſe to make the flagging nine inches thick, eſpecially on the outward ſide next the gravel. This I think, Sir, anſwers all your queries.

Your's, &c.

J. SMEATON.

To Lord Home.

My Lord, Auſthorpe, 5th September 1770.

The very day your letter is dated I was viewing the bridge at Kelſo, and in my journey to Woolerhaughhead had paſſed within ſight of Coldſtream Bridge, and where I ſhould with great readineſs have called had I had intimation that any thing had been amiſs with it. In my way north I paſſed over it in the beginning of July, but as I heard nothing I did not enter into any particular examination; but obſerving the ſtones lying as uſual upon the ſalient points up ſtream, I took it for granted all was right. It was a requeſt I many times repeated to my late worthy friend Mr. Pringle, and to Mr. Reid, that great care ſhould be taken for ſome years to maintain the rough ſtone work round the two piers founded on piles, and from time to time to repair the ſmalleſt derangement till the whole ſhould become ſettled: and I am ſorry to ſee that this, as well as many other public works, has been ſo cramped in the finiſhing, that many eſſential things are left incomplete; and that it is not left worth the while of the perſon who has had the principal hand in the execution, and who muſt be

be beſt able to ſee and judge, and apply timely remedies, to intereſt himſelf therein.

Something of the kind now wanted is always neceſſary to be applied in gravel bottoms, and the caſe is noways difficult if done with judgment: and no better method can be taken than what you have already done, that is to throw in large rough ſtones, ſo as to form a ſlope up againſt the baſes of the piers, and when this is done, to throw a conſiderable quantity of gravel upon them, or ſmall rubble, in order to waſh into and fill up the chinks of the larger ſtones. The leſs this outwork is extended, beyond what is neceſſary to ſecure it a ſufficient natural baſe, the better, as all obſtruction to the free courſe of the river through the arches, is hurtful. It is poſſible that as the work will not be all of a piece, ſome of the ſtones may be deranged by the action of the flood, but thoſe being made good again ſeldom fail a ſecond time, unleſs it be occaſioned by a failure in ſome other place. All piles and wood-work are to be avoided, as the failure of the wood proves ſooner or later a failure in the ſtones. The piles and boards there are the remains of the coffer dams, which it was then thought not prudent totally to eradicate, for fear of diſturbing the gravel; but now that the rapidity of the flood has, I apprehend, taken away the ſurrounding gravel, and let down the wood-work, and thereby ſapped and taken away the gravel from under the ſtones, the latter muſt neceſſarily go down; let therefore the whole be made up with rough ſtones, and as they can no more be ſapped by the running away of the gravel from underneath them, you will find they will lie, and this the better, if thoſe which can be laid by hand are ſo diſpoſed as to lean down ſtream, as I formerly directed; and if it be found, that after a great flood the ſtuff to be laid upon the larger has diſappeared, partly by waſhing into the interſtices, and partly by waſhing away, it muſt be renewed till the interſtices appear filled. It perhaps may be a queſtion, as I expect it is only ſome part of the ſurrounding works that has ſuffered, whether thoſe which have not failed ſhould remain till they do, and then be made up in the ſame manner as before directed, or whether the piles ſhould be now drawn, and the whole made up at once? But this is a matter which, without inſpection, or the Report of Mr. Reid, ſetting forth the condition thereof, I am not enabled to decide upon. But this I am clear in, that if this buſineſs be carefully and properly performed, after all dependence on the wood-work is gone, and ſuch derangements as may happen in the courſe of two or three years repaired, till the whole comes to a bearing, this part of the work will laſt for ages, and in caſe of any future misfortune can always be made good in the ſame way. I beg leave to obſerve that round ſtones will not do; rough ſtones from the quarry are beſt, the rougher they are the better.

In

In regard to forming a dam below the bridge, it is in this place totally unneceſſary, as the piles on which the piers reſt are conſiderably below the water's ſurface in the loweſt ſtate of the river, the work mentioned would be ſtill neceſſary, and a dam would coſt as much as would do the work in the way I mentioned four times over.

I am, &c.

J. SMEATON.

To the ſame.

My Lord, Auſthorpe, 16th Auguſt 1781.

I have been informed by a friend who paſſed over Coldſtream Bridge laſt month, when the water of the Tweed was remarkably low, that he obſerved the rubble laid for the defence of the piers to be much ruffled, and a conſiderable part taken away, and left in the Tweed about forty or fifty yards below the bridge, and that in his opinion the rubble that had been laid, was too ſmall and thin.

On this occaſion, if any thing be neceſſary to be added to my letter of the 5th September 1770, it is, that I would recommend the rubble ſlope againſt the piers to extend thirty feet up ſtream above the ſalient points; and if a bank or ſhoal of rubble were made about thirty or forty yards down ſtream, the place where the preſent rubble is carried to, it would greatly tend to keep the defences about the piers in their place: and as this bank or ſhoal need not be raiſed ſo high as one foot below the ſurface of the water, in the ordinary ſtate of the river, there can be no objection on account of the ſalmon fiſheries; it ſhould be a competent breadth at the top to reſiſt the action of the floods in paſſing over it.

From what has happened, I am apt to think with my friend, that the rubble made uſe of has been too ſmall. As he is not a man of my profeſſion he may be miſtaken, yet as he is of a general good judgment of things, I could not omit giving you this intimation for the public ſervice, as Your Lordſhip had formerly honoured me with your correſpondence on this ſubject. It was the original intention to build all the piers upon the rock; but Mr. Pringle finding the expenſe of pumping run very high, begged that the two piers in queſtion might, if poſſible, be founded on the ſtratum of gravel which laid above the rock; which having been gradually worn away by the action of the floods, has occaſioned the derangements that have ſince happened to the defences; which, however, being carefully attended to and kept up, the piers will reſt with equal ſolidity upon the central matter as at firſt.

I am, &c.

J. SMEATON.

REPORT of ROBERT REID on the State of Coldſtream Bridge.

To the Honourable the Truſtees, appointed by Act of Parliament, for the Roads and Bridges in Berwickſhire.

IT evidently appears from experience, that the ſecuring of the foundation of the piers of Coldſtream Bridge is an annual expenſe, and notwithſtanding all the vigilance and care of the truſtees living near it, the expenſe is ſtill multiplying. The reaſon is obvious; a great many of the guard piles are gone that formerly ſecured the rubble ſtones which were laid about the foundation of the end piers. And immediately after the great flood in the year 1782, they were obliged to lay a conſiderable quantity of large ſtones, which exceeded the limit allotted to them, which was ten feet from the piers which theſe guard piles pointed out. This being the caſe, the water is ſomewhat confined in its paſſage, and when it begins to riſe it runs with ſuch rapidity that it has thrown out the gravel from between thoſe two piers founded upon wood, in great quantities, eaſtward from the tails of the piers. In ſome parts it has gone the depth of four feet, at other parts eight feet, and five feet; and if it ſhould continue to work at that rate, it will bring out the gravel from between the piers, and leave theſe two piers ſtanding upon ſtilts; and may be attended with bad conſequences.

The queſtion will now ſtand, how this is to be remedied? This I have pointed out to be by a dam-head, with a row of piles through the river, and a quantity of ſtones on each ſide of them, about 100 feet or thereabouts below the bridge; and whatever gravel ſtones, or other ſtuff the river brings, it will leave it there, and ſo go on till it has raiſed it as high as the dam-head, and in place of taking away any thing from the foundation, will be conſtantly laying to it; which muſt ſecure your foundation as long as the dam-head ſtands, the piles being in the middle of it, will ſecure it a long time.

Perhaps ſome objections may be made about the ſalmon fiſhing: to obviate theſe, there will be ſome openings left at proper diſtances for the paſſage of the fiſh.

Now this method I am perfectly ſure of being effectual, as I helped to put one of theſe dam-heads into execution, at a bridge built by the Government over the river Tay, in the year 1735, and has been the ſafety of that bridge ever ſince. Before the maſon work was perfectly finiſhed, the river was making whirlpools at the tail of the pier; and after obſerving

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To the Honourable the Truſtees, appointed by Act of Parliament, for the Roads and Bridges in Berwickſhire.

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The queſtion will now ſtand, how this is to be remedied? This I have pointed out to be by a dam-head, with a row of piles through the river, and a quantity of ſtones on each ſide of them, about 100 feet or thereabouts below the bridge; and whatever gravel ſtones, or other ſtuff the river brings, it will leave it there, and ſo go on till it has raiſed it as high as the dam-head, and in place of taking away any thing from the foundation, will be conſtantly laying to it; which muſt ſecure your foundation as long as the dam-head ſtands, the piles being in the middle of it, will ſecure it a long time.

Perhaps ſome objections may be made about the ſalmon fiſhing: to obviate theſe, there will be ſome openings left at proper diſtances for the paſſage of the fiſh.

Now this method I am perfectly ſure of being effectual, as I helped to put one of theſe dam-heads into execution, at a bridge built by the Government over the river Tay, in the year 1735, and has been the ſafety of that bridge ever ſince. Before the maſon work was perfectly finiſhed, the river was making whirlpools at the tail of the pier; and after obſerving

obferving that, all hands went to work to make the dam-head, which remains there to this day.

Another thing would require attention: as the fouth arch is for the moft part of the year dry: formerly, when converfing with Mr. Smeaton about this bridge, he faid it would be of great advantage that the water were brought through this arch, that it might give relief to the reft; and at the breaking of a froft there is commonly a mountain of ice lying in this arch, for want of water to carry it off.

ROBT. REID.

OPINION and DIRECTIONS of JOHN SMEATON, Engineer, for the Prefervation of Coldftream Bridge, upon the Condition thereof, as ftated in the Plan and Report of Mr. Robert Reid, dated October 19th 1784; tranfmitted to him in the Letter of Mr. James Gray of 3d May 1785.

To the Honourable the Truftees, appointed by Act of Parliament, for the Roads and Bridges in Berwickfhire.

Sirs,

I obferved, in my anfwer to the letter of my Lord Home in the year 1770, upon a derangement of a fimilar nature to the prefent, that I had many times repeated to my late worthy friend Mr. Pringle, of Lees, and alfo Mr. Reid the executive mafon, that great care fhould be taken for fome years to maintain the rough ftone work round the two piers founded on piles; and from time to time to repair the fmalleft derangement, till the whole fhould become fettled; that fomething of the kind then wanted, is always neceffary to be applied in gravel bottoms; and that the cafe is no ways difficult, if done with judgment.

Since the year 1770, much greater and more violent floods have happened in all the northern rivers, than had been before pointed out to my experience: notwithftanding which, the fame kind of directions having been punctually and carefully attended to at the bridge at Perth, no derangement has happened to produce any alarm.

In the year 1770, the fpeats of the Tweed had then in fome meafure deftroyed the pile fences, originally driven to form the coffer dams for draining off the water while the piers were founding; and which it was thought improper to draw, for fear of

disturbing

difturbing the furrounding gravel; the interior fpace being filled with rubble ftones, to defend the gravel immediately furrounding the piers within the faid fences; but thofe giving way, let down the ftones contained within them. As it thus appeared that the pile work was not defenfible by its own ftrength and ftability, but that if reinftated, muft be externally defended by the depofition of ftones, I thought proper to advife, that the whole fhould be made up with rough ftones; obferving at the fame time, that it was a matter of queftion which I could not decide without infpection, as the whole of the furrounding works might not have fuffered together, whether thofe which had not failed fhould remain till they fhould fail, and then be made up in the fame manner as thofe already directed; or that the remaining piles fhould be drawn, and the whole made up at once.

It appears however from the prefent report, that by purfuing the methods then directed, the immediate foundations of the bridge have been fo far preferved entire: but as the ftones depofited for the fafety of the foundation have hereby enlarged their bafe and flope, and in confequence fomewhat ftraitened the water-way; and proving too ftubborn to be removed by the rapidity of the ftream, its action has been exerted in removing the gravel between the piers remaining undefended; and has pooled the holes, as particularly fet forth and defcribed in that report.

For my own part, I generally find it right to apply the ftrengthening plaifter immediately to the weak part, and would begin the work by filling up every pooled part, even with thofe parts that remain of four feet deep: and in confideration of the increafed rapidity of the floods within the laft 15 years, I would advife all thefe fillings to be performed with ftones of a larger fize and weight than before directed; (that is to fay) with ftones from a ton to half a ton weight, and to chock in the interfpaces with leffer ftones, of fuch fizes as to make the whole a tolerably regular furface, extending as far as the pools exceed the depth of four feet; and then by way of further fecurity, I would begin an artificial fhoal to act in the nature of a dam, by laying a row of large ftones acrofs the river, at the diftance of 100 feet below the bridge; and then depofiting other ftones above this, bringing the work forwards towards the bridge, and a little increafing in height, to the breath of 30 feet; and fo as to pen the water $1\frac{1}{2}$ or 2 feet deeper under the bridge at low ftill water, than it now is; and then to flope it upwards to the further breadth of 20 feet; making 50 feet in the whole breadth: this will make fo eafy a flope, that the falmon will make their way over it without interruption. I would make the loweft part of it, for the water's ordinary paffage in dry times, in the place where it now is; but fo near upon a level, that in the fmalleft fpeat it will flow over its whole length.

It

It appears on this occasion, when the work of the dam or ſhoal is eſtabliſhed, as it will interſect the deep part of the river, that it will be proper to ſurround the pier that ſtands upon the rock, with a ſtratum of large ſtones chocked in with ſmaller, ſo as to form a bed or ſtratum of about two feet thick; and to a diſtance of ſix or ſeven feet from the baſe of the pier, where the rock is bare on the north ſide; and till it meets the ſtone of the rubble for defending the north ſide of the ſecond pier: but at the down ſtream end to be continued till it meets the foot of the ſlope of the dam; by which means the aforeſaid bed will be ſupported.

The uſe of the depoſition of this bed round the pier upon the rock, is to preſerve the floor of timber of ſix inches thick, that lies between the rock and the baſe of the ſtone work of the pier; for though it will not rot, yet the rapidity of the water running by, and acting upon its outward border, will doubtleſs in proceſs of time corrode it, and may undermine the outſide, ſo as to cauſe the outer to ſeparate from the interior core. I do not imagine that any eſſential harm can as yet have happened from this cauſe; but it ſeems now time to ſet about ſuch an expedient, to prevent future miſchief.

When the work is brought to this ſituation, it will be proper to make the trial of another winter, in the courſe of which I would expect that part of the preſent bottom that does not now lie above four feet deep, being undefended, will be further pooled, and ought then as ſoon as perceived to be filled up even with the other, with heavy matter of the ſame kind; in conſequence of which the whole will become capable of reſiſting the action of the water; and when by attention the whole of the ſoft places are made good, then it may be expected the bottom will remain untouched for ages. I cannot ſay I would adviſe the ultimate performance in this manner juſt now, becauſe it will coſt more to work away the gravel under water to a ſufficient depth, than it will to fill the cavity when made; and if a ſtratum of ſufficient weight and ſolidity were depoſited over the preſent, it would too much obſtruct the water-way.

In regard to the erection of a dam-head, without filling up the pools, though it is very poſſible the river may do it, yet it is very poſſible that it may not: and though this may be the caſe at Tay Bridge, this is but a ſingle inſtance; and the operation of rivers is ſo very various according to ſituation, and I have ſeen ſo many dam-heads where the water has not filled them with gravel, that I cannot recommend it to depend upon this alone: whereas by filling the extra depth of the pools, and forming a ſhoal or dam of a lower kind, laying firſt a row of the largeſt ſtones by way of footing to the reſt, no piles will be wanted, which are both expenſive and tedious in the execution. An application of this ſame kind I recommended at Kelſo Bridge, where notwithſtanding a dam that had for years ſubſiſted below, the piers were become ſo pooled and undermined, as to put the bridge

bridge in imminent danger: beſides, in this mode of working, after the ſtones are won from the quarry, there will not be the need of a maſon's tool to be laid upon them.

Furthermore, I apprehend it will be of utility and very proper that the ſouth arch ſhould be deepened to the ſame level as the pool when filled as already directed; and when this freſh ſurface pools further, to be treated in the ſame manner as the reſt.

J. SMEATON.

Grays Inn,
16th *May* 1785.

AT a Meeting of a Committee of the Truſtees for the Berwickſhire Turnpike Roads and Coldſtream Bridge.

Coldſtream, 9th Auguſt 1790.

Preſent — Eight Truſtees, and Lord Swinton, Præſes.

Inter alia, The following Memorial concerning the Bridge over the Tweed, near Coldſtream, was laid before the Meeting:

About ſix years ago the river Tweed being very rapid, formed ſeveral pools or weels round the pillars or piers of the bridge, particularly the middle piers, which are founded upon wood, whereby it was thought the bridge was in conſiderable danger.

That thereupon Mr. Smeaton was conſulted, and gave in a very full advice to the truſtees, which was, in general, to build a dam-head or dike acroſs the river, about ſeventy feet below the bridge, and of a height about two feet above low water mark.

That this was done accordingly; but ſome time after it was made, upon a ſuggeſtion of ſome of the truſtees that if it was continued in that manner it would be an obſtruction to the ſalmon getting up the river, a cut was made in the middle of the dam-dike, about ſeven feet wide, by way of making a free paſſage for the ſalmon.

Mr. Reid, maſon, who is employed to take charge of the bridge, ſtates that the guſh of water paſſing through this opening makes a hollow in the channel of the river, both above and below the dam-dike, and particularly it ſweeps away much of the gravel which the river brings down from above the bridge, and which would otherwiſe remain above the dike, ſecure its permanency, and prevent the blowing round the piers.

Mr.

Mr. Reid farther informs the truftees, that in cafe a paffage through the dike for the falmon coming up the river was neceffary, it might perhaps be fafe to fill up the prefent cut in the middle of the dam, and in place of it to make another opening at the fouth end of the dam-dike, and oppofite the fouth arch, which is founded upon rock, and where the river runs upon or near the rock.

The truftees having confidered the above reprefentation from Mr. Reid, and having themfelves vifited the river, which happened then to be fpeat or flood, fo that they could not fee the effects of this gufh of water either above or below the dam, they had various opinions concerning this matter; fome thinking that there was no need of any opening at all for the paffage of the fifh, others thinking that the fifh would be ftopt except in fpeats; but all agreed in this, that the dam-dike had been of the greateft advantage to the bridge, and that the prefervation of the dam was the falvation of the bridge; it was fit to confult Mr. Smeaton what was neceffary to be done in this matter, viz. whether, in his opinion, any opening was neceffary for permitting the fifh to pafs up the river, and whether there was any danger from fuch an opening, and whether, if there was any neceffity for it, it ought rather to be on the fouth fide than in the middle? and that he would be pleafed to communicate his advice and particular directions on the whole matter.

And in order that Mr. Smeaton may be the better enabled to give an opinion, they direct foundings to be made by Mr. Reid and Mr. Sharp, furveyor, in Coldftream, of the depth of the water both above and below the dam, and particularly in the channel of the opening; and to be fent to Mr. Smeaton along with the memorial. Extracted from the minutes of the truftees book.

JOHN TURNBULL, Clerk.

REPORT of JOHN SMEATON, Civil Engineer, upon the State and Condition of the Bridge of Coldftream, as ftated in the Memorial to the Truftees of the Berwickfhire Turnpike Roads, and Coldftream Bridge; the 9th Auguft 1790.

When I had the honour of delivering my opinion upon the proper remedy for curing the defects then already felt, and further apprehended, in the foundation of Coldftream Bridge,

Bridge, about fix years ago; wherein I advifed a dam-dike to be built acrofs the river about 70 feet below the bridge, and about two feet high at low water; I ftated this height, in view that it fhould be no obftruction to the falmon getting up the river; having feen feveral inftances of even upright dams of four feet high and upward, in falmon rivers, and which were not confidered as an obftruction to the paffage of the fifh; as they are frequently feen to leap to a greater height than that. I could not therefore conceive that at two feet high, upon a *floping* current, the leaft objection could arife, or be thought of. I am very happy to find that the expedient propofed and executed, has fo effectually anfwered the intention.

Had I been confulted concerning the expediency or manner of the cut fuggefted to be made through the body of the dam, I fhould certainly have delivered it as my opinion, that none was in reality neceffary: but if to fatisfy the apprehenfions of thofe who thought themfelves interefted in the fifhery, the truftees fhould think fomething neceffary, I fhould never have advifed the execution to have been in the way it is fuggefted by this memorial to have been done; viz. *a cut of* SEVEN *feet wide in the* MIDDLE *of the dam-dike.*

I think it very lucky that this cut, being in the middle of the river, and confequently where in fpeats the principal current muft be, has not by degrees grown wider and deeper, fo as have deftroyed the dam; and thereby have brought the bridge itfelf into that kind of danger which this work has been intended to guard againft. I therefore recommend that the cut be filled up and made good, as at firft; and in cafe, to fave objections, an opening muft be fomewhere, it will, as Mr. Reid very properly fuggefts, be much the fafeft on the fouth fide of the river, where the river runs the fhalloweft, and upon a rock. Indeed, I fee no objection to remove the dam-dike fo far entirely that the water may flow freely and without obftruction through the whole of the firft arch of the bridge from the fouth; and oppofite to the firft pier begin the dam-dike, to rife gradually fo as to come to its prefent height oppofite to the fecond pier from the fouth. Indeed this flope will be formed in reality by the fubtraction of the prefent matter, but yet it muft be taken care to be caped with fuch new matter or weighty ftones as are likely to lie and refift the current in fpeats.

J. SMEATON.

Gray's Inn,
26th November 1790.

NEWCASTLE BRIDGE.

REPORT of JOHN SMEATON, Engineer, concerning the State of that Part of Tyne Bridge, between Newcaſtle and Gateſhead, which is in the County of Durham.

HAVING carefully inſpected the ſouth part of Tyne Bridge the 16th of September laſt at low water, I found it in a general ſtate of diſrepair: but as it has been originally ill built, I look upon it as impoſſible, after ſtanding ſo many years, to render it perfectly ſound, unleſs the whole was new built, which is not the preſent propoſition; yet by occaſional repairs ſeaſonably applied, it may laſt for many years. I ſhall therefore take the arches in order, and confine myſelf to the pointing out of ſuch things as more immediately call for aſſiſtance.

The firſt arch beginning from the ſouth ſide, is in a great meaſure blocked up by cellars for convenience of the houſes above, and has no current of water through it, when the low water is below the ſterlings or jetees, as they are called, which ſurround all the piers in the manner of London Bridge: this arch ſeems at preſent to want no material repair.

The ſecond arch has a paſſage between the jetees at low water. The aiſlering of the piers on both ſides this arch wants repairs, many of them being looſe, and ſome of them dropped out: the aiſlering on the north ſide appears worſe than it really is, having been built originally bulging, at leaſt ſo it ſeems to me.

The whole or greateſt part of the arches of this bridge have been lined with ribs, as was cuſtomary formerly, with a view to ſtrengthen them, but it ſo happens that a great many of thoſe ribs have ſeparated themſelves from the arches that they originally were in contact with, and have tumbled down, one of the ribs now remaining in this arch; viz. that on the up ſtream or weſt ſide, is ſo far ſeparated from the arch, and is in imminent danger of falling, that to prevent miſchief to any that may be under it when it happens to fall, it will be proper to take it down: I do not apprehend it to be any ways neceſſary to rebuild it, becauſe I cannot ſuppoſe it has ever been of any real uſe.

In

In the middle of this arch the ſtone work is entirely perforated by an area of about four yards by ſix; and as the bridge has been ſo conſtructed at firſt, this area had once been covered by a draw-bridge by way of defence, being ſo placed that, if open, the paſſage over the bridge, as it now is, between the houſes would have been ſtopped thereby. This area is now floored with timber covered with earth, and paved at the top like the reſt of the bridge, ſo that when carriages go over this part of it, the vibration of the timber makes it appear to ſhake. The main timbers are pretty ſtrong, but the whole has been very roughly executed, and has all the appearance of a job done in a great hurry. It ſeems alſo to have had ſome repairs occaſioned by the rotting of the ends of the great beams which have been ſupported by piers put under them; ſome of the ſmall wood that is ſupported by the greater appears to be decayed; but while ſo ſupported nothing of great conſequence can happen. In fact, as I don't find the ſtate of this flooring ſenſibly different from what it was when I viewed it in the year 1765, for that reaſon it may be ſuppoſed poſſible to continue for a number of years to come; but as it is a piece of work ſo put together, that one cannot anſwer for it, a failure may happen when it is leaſt expected; and as the lives of men depend upon it, and it is in a viſible ſtate of decay, it appears to me that it ought to be repaired; and as it is very probable it may never be wanted again to ſerve the original intention, while it is doing I would recommend this area to be arched with ſtone, and as the centre may be erected underneath, and every thing prepared for turning the arch before any thing is diſturbed upon the top, I apprehend all may be with eaſe completed in three days ſtoppage.

The next arch has loſt all its ribs, yet ſhows no ſigns of infirmity, except that as the pen ſtones are in a double layer, compoſing an interior and an exterior arch, the former is a little ſeparated from the latter, on the down ſtream ſide of the ſouth haunch. Some repairs are wanted in the ſetting of the jetees of this arch, as alſo more or leſs in all the reſt.

The fourth arch from the ſouth ſide, or ſecond from the draw-bridge arch, is called Keelman's arch: it has originally had five ribs underneath it, of which there is only one remaining; but it ſhews no loſs by the want of them, the up ſtream ſhoulder of the pier on the ſouth ſide of this arch, wants repairs; and together with the reſt a number of ſmall articles which it would be uſeleſs as well as tedious to mention.

As the whole of the repair is a kind of jobbing work, there is no ground upon which to form an eſtimate of the expenſe; for when part of an old edifice is pulled down in order to be repaired, it often diſcovers ſomething unforeſeen, of which a repair is equally neceſſary

ceſſary; for this reaſon (except the arching of the draw-bridge area) it cannot well be done by contract, becauſe a contractor will not do more than originally appeared, and thereby the ſore may be left unbottomed; and if done by day-work, the expenſe will depend greatly upon the honeſty and addreſs of the workmen. But I ſhould imagine the whole, ſtone-arching in the draw-bridge included, may be done as well as the ſtate of the bridge will admit of, for 150l., or at moſt, 200l.

J. SMEATON.

Auſthorpe,
October 18th 1769.

N.B. This part of the bridge belongs to the ſee of Durham. It fell down in a great flood in 17 ; and was rebuilt in its preſent form by Mr. Mylne.

REPORT of JOHN SMEATON, Engineer, upon the State of that Part of Tyne Bridge, belonging to the Town of Newcaſtle.

HAVING carefully viewed the north part of Tyne Bridge, the 30th of April 1771, being attended by Mr. Craiſter and Mr. Gunn, I am of opinion as follows.

That the whole of this bridge is founded upon piles ſawn off above low water mark, in the manner of London Bridge, and in the ſame manner, each congeries of piles for ſupporting the pillars, is ſurrounded with a work of defence called ſterlings or jetees, which, reaching from two to three feet above water, each probably one or two feet above the heads of the bearing piles, thereby defend them from decay, and from being ſapped at the bottom by the immediate action of the water upon them. Thoſe jetees, however, being chiefly conſtructed of timber, and being immediately expoſed to the action of the water, are always in a periſhing ſtate, and therefore themſelves gradually come under a courſe of repair, though they ſeem pretty effectually to have defended the bearing piles for ſupporting the ſuperſtructure, as there does not appear to me to be any ſhrink of the foundations which at preſent can be noticed. The jetees from the middle pier, that divides the counties, to the north ſhore, appear to be at preſent in tolerable order; ſome few ſtones are wanting from the upper ſurface, but which will be eaſily replaced in courſe of a repair.

The whole of the ſuperſtructure has more ſenſibly felt the effects of time, having been originally very ill built, and in general of too ſmall ſtones, and not of the beſt kind; this

added to the great wear and tear occaſioned by the frequent running of the keels againſt the piers and hips of the arches, has produced derangements that can never be effectually mended, becauſe the new work, which from its nature muſt be ſuperficial, can never be firmly united to the old, and therefore, thoſe repairs cannot be of long duration, as they are eaſily diſplaced by freſh ſtrokes, being chiefly retained by cramps of iron: from theſe cauſes almoſt the whole of the aiſler facing of the piers is looſened from the core of rubble work within, and which appears alſo to have been the caſe for a courſe of years back; the arches reſting upon ſtones which are very much decayed, and which cannot be replaced without danger of bringing down the arches they ſupport; this renders the whole ſuperſtructure in ſo ill circumſtanced a ſituation that nothing laſting can de done at it.

It is not eaſy to fix the duration of a piece of ſtone work, as we daily ſee inſtances of old buildings hanging together in a ſurpriſing manner: and as the infirmities that I have pointed out are not of very recent date, nor any thing happened that is particularly alarming, I ſhould expect that with conſtant attention to repair its defects as they gradually ariſe, this bridge may be ſupported many years longer; however, as it is not poſſible to be aſſured how long it may laſt, its apparent condition is ſuch as would readily induce me to recommend the thoughts of a new one, if I could ſee a poſſibility of adviſing any thing to which there are not very manifeſt objections.

The moſt deſirable ſituation ſeems to be a bridge below the preſent one, as being moſt central to the town; but the depth of water there is ſo great as to make ſuch an undertaking exceedingly expenſive.

The moſt eaſy, leaſt expenſive, and what could be done in far the ſhorteſt time, would be to build a new ſuperſtructure upon the old foundation; but as upon this plan it could not well be made above four feet wider than the preſent breadth where wideſt, and as there would be a neceſſity of continuing the preſent jetees, I apprehend this meaſure would ſtand univerſally condemned.

To put down new piers in the preſent ſituation, upon new foundations, ſo as to afterwards take away the jetees, would greatly prolong the time, and add to the expenſe and difficulty; eſpecially as the places of the new piers would be obliged to conform to the old ones, and thereby increaſe the number of piers that would be neceſſary or eligible in an entire new ſtructure.

To build a bridge above the present one, would be done at less expense than in any case, if an entire new one, but would be less central than the present.

I have endeavoured to throw together these general thoughts, that it may be clearly seen how the matter hinges. With respect to the current repairs that are now necessary, and of which it is not possible to make an estimate, being such as have usually happened; it is, however, necessary to say something respecting the rebuilding the land-breast and first arch from the north side.

The north arch is certainly in the most ragged condition of any; but being a small arch is in less danger of falling. The immediate rebuilding thereof depends upon another matter. If a building is to be erected upon the key-wall, connected with the land-breast, the land-breast wall is so bad above low water, as not to be safe to make any building intended to be durable upon it. The key-wall cannot properly be rebuilt, without doing that part also whereon the last arch of the bridge rests, being connected together. That part upon which the arch rests, cannot be done without taking down the arch, and when down it will not be proper to rebuild the arch without new doing the face of the pier, whereon its other haunch is to rest. The neglect of which, in rebuilding two or three other arches contiguous, which appear to have been done not very many years ago, will occasion their not being of longer duration than the old ones. In fine, if there is no immediate necessity of building upon the key-wall, and if there was any prospect of a new bridge, then the rebuilding of the said arch may be deferred; but if the bridge is to be supported as long as it can be, then I advise at all adventures to build up the wall and arch in the most effectual manner.

The great arch, which is next the division of the counties, and the sixth from the north shore, as also the arch next it north, commonly called the white arch, or fifth, appears to have been original. Those arches are built with ribs, which are now so much settled as to bear very little weight: two out of five in the great arch, and three out of five in the white arch are tumbled down, or have been driven down by the keels running against them; at present the north end of the lower rib of the white arch has by a stroke from a keel been driven sideways several inches out of its place; it is possible it may so hang for years; but as it is plain from this that it supports nothing, and as another stroke in the same way by another keel will infallibly bring it down, and by the fall thereof lives may be lost, it seems therefore adviseable to take it down.

J. SMEATON.

Newcastle,
6th *May* 1771.

P. S. When

P. S. When the north arch is built, it seems practicable to make a foot passage on to the quay, which, as it will greatly ease the present narrow avenue to the bridge, will deserve consideration *.

MINUTES of a View of Newcastle Bridge, 30th April 1771, by JOHN SMEATON, Engineer.

Great Arch or 6th.

The great arch, being the sixth from the north side, beginning at the middle of the pier on the south springer of the said arch where the counties divide.

The down stream angle of the said pier between the town and the Bishop of Durham is in bad repair, and the face of the aisler wants new pointing, and filling up to high water mark, which is in general the case with the whole bridge.

When any of the salient angles are new done, I would advise their being rounded by a sweep of about 18 inches radius, by which means they will be less liable to be broken and dislocated by the keels, and that all the mortar used within the tides mark be made with pozzolana rather than terras.

The great arch has been originally built with five ribs, of which the two outside ones are gone, the penstones making the cover being put on joint and joint.

In the down stream course of penstones, a bad stone near the south springer ought to be in part screeded off, and supported by a fresh ingrafted stone. Near the north springer of the great arch both on the up stream and down stream sides, the joints in the penstones are become open; those most perished to be wedged and pointed.

Pier North of the Great Arch, or 5th from the North Shore.

Several cramps are loose, and stones out of the face, which should be repaired and pointed as before mentioned; in the jetee north side of the pier, some stones are out and want repair.

* Nothing was done, the bridge tumbled down in the greater part, and this portion thereof belonging to Newcastle, was rebuilt by Mr. Wooler, military engineer.

White

White Arch, or 5th.

This arch was alſo originally built with five ribs, of which one up ſtream and two down-ſtream are gone, the penſtones near the ſouth ſpringer on the down ſtream ſide are ſharped off, and ſhould be freſh abutted. The north ſpringer of the down ſtream rib appears from the blow of a keel to have been driven ſeveral inches ſideways out of its place, and as from hence it appears to ſupport nothing, and may be driven down and do damage by ſuch another accident, it ſeems beſt to take it down, nor can any new rib be erected, ſo as to anſwer any good end. The joints of the penſtones towards the north ſpringer are periſhed and want wedging.

Pier North of the White Arch, or 4th.

The outſide ſtones in a general ſtate of decay, but no particular failure; like the reſt it wants new pointing.

The Tower Arch, or 4th.

This arch ſeems to have been new done ſince the original, but appears to be the firſt of thoſe that have been rebuilt; it is without ribs, and not very ſubſtantial.

The penſtones at the ſouth ſpringer on the up ſtream ſide are broken, but may be eaſily repaired. The penſtones at the north ſpringer both up and down ſtream are a good deal galled by the keels.

The Tower Pier, or 3rd.

The aiſler on both ſides that ſupport the arches are a good deal waſted; the down ſtream point of the jetee has been damaged and wants repair.

The Arch North of the Tower Pier, or 3rd Arch.

This arch has been rebuilt without ribs in man's memory, is in tolerable good order, but is ſprung from bad bearings.

The Pillar North of the Tower Pier, or 2nd Pillar.

The up ſtream point wants repair, and ſeveral ſtones are out of the faces, which need replacing.

The firſt Pillar from the North Shore.

This pillar ſeems in general in as good order as any, but its aiſlering depends altogether on cramps, and being out of the common road of the keels is not ſo apt to ſuffer thereby.

The firſt Arch next the North Shore.

This arch is at preſent in a very ſhattered condition, though part of it ſeems to have been rebuilt within the compaſs of a few years, the oldeſt part of it does not appear to have been original, but when rebuilt has been haſtily done with bad workmanſhip and materials; the new part which is on the up ſtream ſide, has been very ill abutted, for it reſts upon a baſe of about 18 inches broad at the north abutment, and is gained on upon the old work till it comes to the breadth of five or ſix feet.

The abutment of the north arch is upon a part of a quay wall, extending both above and below the bridge, the whole of which above low water is in a ſhattered condition, and ſeems very improper to build upon without firſt rebuilding the wall itſelf, at the ſame time taking down the north arch, and rebuilding both at the ſame time.

When this is done, I adviſe to clear away the north face of the firſt pier, to at leaſt four feet in breadth, quite down to the foundation pile heads or platform; and if any thing there appears deficient to make it good with new, then to raiſe up this face of the pier with large and good aiſler, in order to reſt the ſouth end of the arch thereon, by this means this will become a part of a new ſuperſtructure, and the reſt being gradually ſerved in the ſame way, will in time produce in effect a new erection.

It ſeems practicable to increaſe the breadth of the bridge ſo as to make it about four feet wider than at preſent, that is, about 20 feet wide within the parapets; 16 feet may be allowed for the carriage-way, which will admit two carriages to paſs freely, and leave four feet for a raiſed walking path.

It is alſo practicable to make a foot-paſſage from the bridge through the old building to the quay, and from thence immediately to the ſand hill, which will greatly relieve the preſent narrow avenue to that end of the bridge.

N.B. The jetees being chiefly timber, are in a general ſtate of decay, but ſeem at preſent in tolerable order; what is moſt amiſs has been particularly pointed out.

J. SMEATON.

Newcaſtle,
9th May, 1771.

A REPORT relative to Tyne Bridge.

THIS bridge having been erected some centuries ago, upon the principles that were then in common use for such edifices, as may be seen from many of the old bridges over great tide rivers in England, and also in several parts of Europe, namely upon stilts, surrounded with a kind of basement called starlings; has always had the same inconveniences and imperfections attending it, to which all others of this kind are subjected.

The stilts are a great number of large piles driven down into the bed of the river, supporting a timber platform or framing under each arch a little above the lowest water of the river, upon which the masonry is established, and those stilts being surrounded with a row of close piling at the distance of several feet, and the intervals filled up with gravel and other stone materials, thrown down at random; and the whole connected with proper timbers, and paved down at top with large stones, a few feet above low water mark, form the footing or basement for the security of the pier, which is called a starling.

Upon these principles this bridge has been hitherto supported, though the river is subject to rapid floods and drift ice in the season, without suffering any thing very considerable, except in one or two of its arches, within the memory of man.

The total breadth of the river between the quays or abutments being 539 feet, the piers or solids of the bridge took up or occupied a third part of it, and when the tide fell below the top of the starlings, they took up somewhat more than one half of the free water-way, immediately above bridge; and this great contraction of the water-way has at length contributed its effects towards bringing about its ruin, by increasing the rapidity of the stream passing under it, so much as to gull away the ground under the arches, sweep away some of the starlings, undermine the stilts, and throw down or render incapable of repairs, five of the arches out of ten whereof this bridge was formerly composed. The arches of the bridge itself are likewise too low, seven out of the ten being totally filled up with water above their crowns or key stones, by the late flood of the 17th of November last; which flood produced this, and many other unhappy events of the kind upon this and the neighbouring rivers.

This flood was three feet six inches higher at this bridge than the memory of man or tradition has ever taken notice of; and the ground on the east or lower side of the bridge is gulled away so as to produce a depth of twenty-seven feet six inches of water at low

water, when at a medium there is only seven and eight feet depth in the river immediately above the bridge, or on the west or upper side of it, and this circumstance is now mentioned to shew the danger the four remaining arches still continue exposed to, by standing as it were upon the *edge of a precipice.*

The inconvenience just now mentioned, arising from contraction of water-way by this manner of construction, and which at length has been fatal to the edifice itself, is far from being the only one which this mode of proceeding occasions; the trade now carried on upon this river, so necessary to the kingdom in general, requires many hundred of keels with coals, and other small vessels, to pass and repass under this bridge almost every tide, both in the day time and in the night. The starlings which project from six to eight feet from the piers, under each of the arches when covered a little by the tide, expose them unavoidably to frequent damages and losses, and often to utter ruin and destruction. And of such events, gentlemen conversant in the trade are sufficiently acquainted with numberless instances, so as to ~~make it totally unnecessary to~~ mention any further, than that the starlings themselves frequently suffer in the rencounter, and incessant blows contribute to their wanting frequent and expensive repairs.

Other inconveniencies attending this bridge must now be mentioned, which are sufficiently known to every person who has had occasion to pass over it; one of which is the steep ascent from the south end of the bridge, rising one foot in seven or eight for a considerable space, with the confined narrow street all the way, which renders the whole extremely dangerous to every passenger, whether in a carriage, on horseback, or on foot, and frequently occasions great interruptions and confusion, when carriages or a number of passengers happen to meet upon it; and being the principal road of communication between Scotland and the southern parts of the kingdom, exposes every individual to those hazards, who has occasion to make use thereof. The other inconvenience is the narrowness of the bridge itself, which within the parapets is 15 feet wide only, and in several places reduced to 9 feet by buildings and other obstructions, and equally productive of the last mentioned hindrances, dangers and delays.

After this detail of circumstances relative to this bridge, the next consideration, of course, must be the manner of restoring it to public utility; and, in order to form a proper judgment hereupon, many trials, in order to ascertain the nature and quality of the ground close to the piers and starlings of the bridge, have been made by borings into the bed of the river, in most of which it was found clogged or filled up with loose stones or gravel, to the depth of 12, 15, or 17 feet below the bed, and afterwards a loose sand

with ſmall gravel for 10, 12, or 15 feet more, and at a medium beween 30 and 40 feet deep from the ſurface of low water before a ſolid bottom was met with, which on the ſouth ſide of the river appeared to be a ſtiff clay, and on the north ſide a hard compact gravel.

Under theſe circumſtances, the difficulty of reſtoring the part of this bridge which is fallen to the former ſtate, *without the uſe of ſtarlings*, will be ſufficiently apparent to every perſon converſant in theſe matters; and though it may not be an impoſſibility in point of art to do it, ſuppoſing that time and expenſe were unlimited, yet it is one of thoſe things that do not ſeem capable even of an eſtimate: and if ſtarlings ſhould be admitted, and the former method of conſtruction allowed of, the difficulty of eſtabliſhing them in a ſolid manner, as well as the foundations of two of the piers, which are totally overturned in ſuch a heap of ſtones and rubbiſh, not only fallen down at preſent, but which appear from the borings to fill up the bed of the river to the depth above-mentioned, would be ſo great, and the execution ſo tedious, that it is difficult to form a judgment what the expenſe would amount to; and, after all, the bridge would be eſtabliſhed with every inconvenience that now attends it, and which have already been enumerated, and at laſt remain equally expoſed to the danger of being overturned by the next great flood, as well from the defects in the manner of eſtabliſhing the foundations as the contracting of the water-way, and the want of a proper elevation of the arches.

In order to aſcertain the nature of the ground under the bed of the river, two ſets of borings have been made acroſs it, the one about 50, and the other 100 yards above the preſent bridge, the latter from the place called the Javel Groop, to the oppoſite ſhore, from both of which a maſs or body of looſe ſand mixed with ſmall gravel from 12 to 30 feet in thickneſs or depth from the bed of the river, appears to cover a ſtiff clay, inclining from the ſaid ſhore to near the middle of the river, and a maſs of the ſame ſand from 30 to 40 feet in depth, covers a hard compact gravel from the middle to the north ſhore, conformably to the borings made at the bridge itſelf, which have already been mentioned.

As the laſt mentioned place, or near it, ſeems to be the moſt convenient ſpot for erecting a new bridge whereby the inconvenience attending the old one might be removed, and, at the ſame time, preſerve the beſt practicable communication from the town to the oppoſite ſhore, it neceſſarily remains to procure by art the means of eſtabliſhing a ſolid foundation upon this great maſs of ſand and gravel; but as a detail of this part would run to too great a length, it may at preſent ſuffice juſt to mention the outlines of this propoſition,

propoſition, which are to ſpan the river with ſeven arches only, whoſe piers or ſolids may not take up more than one-fifth part of the water-way, to lay the foundation of the piers and abutments ſeveral feet below the bed of the river upon a ſufficient number of ſtout piles driven down under them, and to circumſcribe each with a border of plank piling driven cloſe to the foundations, and thus at once to remove the danger and inconvenience to the navigation ariſing from the ſtarlings, and at the ſame time to admit of four-fifths of the breadth of the river to be free water-way: to give this new bridge more elevation than the old, to conſtruct the piers and arches with large blocks of the hardeſt and moſt durable ſtones the country affords, to make the breadth of the bridge within the parapets 30 feet wide at leaſt, with a paved way for foot paſſengers on each ſide, and to ſuffer no erections or buildings whatever to occupy any part of that ſpace, to keep its landing on the ſouth ſhore as much elevated as poſſible, and to bring the road to join it 40 feet wide at leaſt, from the top of the ſteep part of Battle Bank near the Half-moon Lane in a winding courſe round the hill, and by this means to reduce the deſcent or aſcent to about 1 foot in 19 or 20, or thereabouts, which will not be very perceptible; to open the communication from the north end of the bridge to the *Cloſe*, and after allowing a ſufficient area or void ſpace at each end of the bridge, its communication both ways will be rendered as convenient to paſſengers and carriages as it is capable of being made.

In order to communicate the road through Pipewell Gate, a dry arch can be made in the abutment; and to enable the inhabitants of that place, and the lower parts of Gateſhead, to go over the bridge in the readieſt way, a flight of ſtairs can be erected from Pipewell Gate to the top of the bridge on one or each ſide of the ſouth abutment, if thought neceſſary.

It is, no doubt, an objection to the new placing of the bridge, that it will be detrimental to thoſe who have houſes in the thoroughfare down the Battle Bank, but when buildings happen to be erected in a place in ſuch a manner as to be totally inconſiſtent with public accommodation, thoſe partial inconveniences muſt either give way to the greater convenience of the public, or the public muſt ſubmit to the having them entailed upon it to perpetuity: but to ſhew this in a clearer light, let us ſuppoſe a new bridge built in the old ſituation, whoſe ſuperſtructure is raiſed at the ſouth end as much as the poſition of the preſent piers (which at all events it ſeems neceſſary to conform to), will admit of, then if a gradual ſlope be continued from the brow of the Battle Bank (where it begins to be ſteep, that is about 70 yards north of Half-moon Lane) to the bridge, it will form a ſlope of about 1 in $12\frac{1}{2}$, which is not to be called an eaſy one; and in this caſe

case the surface of the road will be in some places near the bottom of the Battle Bank, 26 feet above the present pavement; so that the greatest part of all the houses down the Battle Bank must be rebuilt; nor can the road through Pipewell Gate be communicated with the bridge for horses or carriages without forming a slope almost 100 yards into Pipewell Gate, which will in like manner induce the necessity of rebuilding there, and the same of Hill Gate.

The slope may indeed be eased by beginning at Half-moon Lane, and cutting down the breast of the bank, but this will not bring the slope under $14\frac{1}{2}$ to 1; the height of the road above the present pavement will be nearly the same towards the bottom of the bank, and the set of houses where the ground will be cut, being undermined or left considerably above the pavement, will also need rebuilding to render them convenient, and after all, the narrowness of the street will be a permanent inconvenience, which cannot effectually be remedied without totally rebuilding the whole of it.

It seems, therefore, that there is no other choice on this matter, but either to rebuild the bridge upon its former principles, or to choose a new situation. It is not to be doubted but the bridge may be restored to what it was by proceeding upon the old plan, at less expense and in less time than the building of a new one; but the inconvenience of passage over and under before mentioned remaining with the public to perpetuity, can scarcely be counterbalanced by the saving of any moderate sum of money, nor can the public be well accommodated with a temporary bridge without being at a much greater charge.

It is not possible to judge completely of the expense of building a new bridge, till a just plan thereof is formed, and from thence an estimate made by a regular induction of particulars. But as this alone is in reality a work of time, to enable the gentlemen concerned to form their judgments of preliminary matters, we judge from the execution of similar works, that a bridge may be built at or near the Javel Groop to the opposite shore, including the extra expense on account of the whole bed of the river being a mass of sand, for the sum of 50,000l., from shore to shore, that is, exclusive of landworks and purchases. A bridge of this kind will probably take seven years to execute; and we are of opinion, that to build a new bridge in the old situation, and on the same principles as before, cannot be executed for less than half the money, and will take half the time,

From

From this proposition, the necessity of purchasing a considerable quantity of buildings and other private property for the use of the public, will be very apparent, in order to make the access to the bridge convenient on both sides of the river, and if all this were not wanted for the above mentioned purposes, a great deal would be absolutely necessary to be had for establishing yards and sheds for the workmen for performing the many different operations the edifice itself would require.

As the time necessary for completing this work will be so considerable; a better communication than the ferry already established, may probably be judged unavoidable during so long a space of time. In this case, a temporary bridge of timber materials, erected upon the stumps of the old piers, so as to join the four remaining arches with the abutment remaining on the south or gateshead shore, will be attended with the least expense and inconvenience of any other method, its whole length being only 320 feet, which is about $\frac{1}{7}$ parts breadth of the river. For effecting this, a proper design with a construction or detail of every particular, is now given in, and the expense computed at about 2400l.

Before this work can be performed, the single arch remaining towards the middle of the river must be taken down, and a little time will show whether this may be attempted with safety to the workmen, when it can be well ascertained, that the opening or rent therein has not increased any more for any considerable space of time. It is further recommended to take up the remains or ruins of the three arches and piers next gateshead shore, leaving the platforms or remains of the piers for establishing the legs of the temporary bridge upon; the performing this as speedily as possible, will procure more free water-way to the river, and in course some advantage as to the safety of the four remaining arches of the bridge, in case of another flood, by allowing the stream to pass more freely on the opposite shore. When the new bridge with its communications is completed, the temporary bridge, with the remains of the old bridge, may be taken away, and the river freed from its incumbrances to the navigation.

J. SMEATON.
J. WOOLER.

Austhorpe, January.

To Sir Walter Blackett Baronet, the Aldermen and Common Council of Newcastle-upon-Tyne.

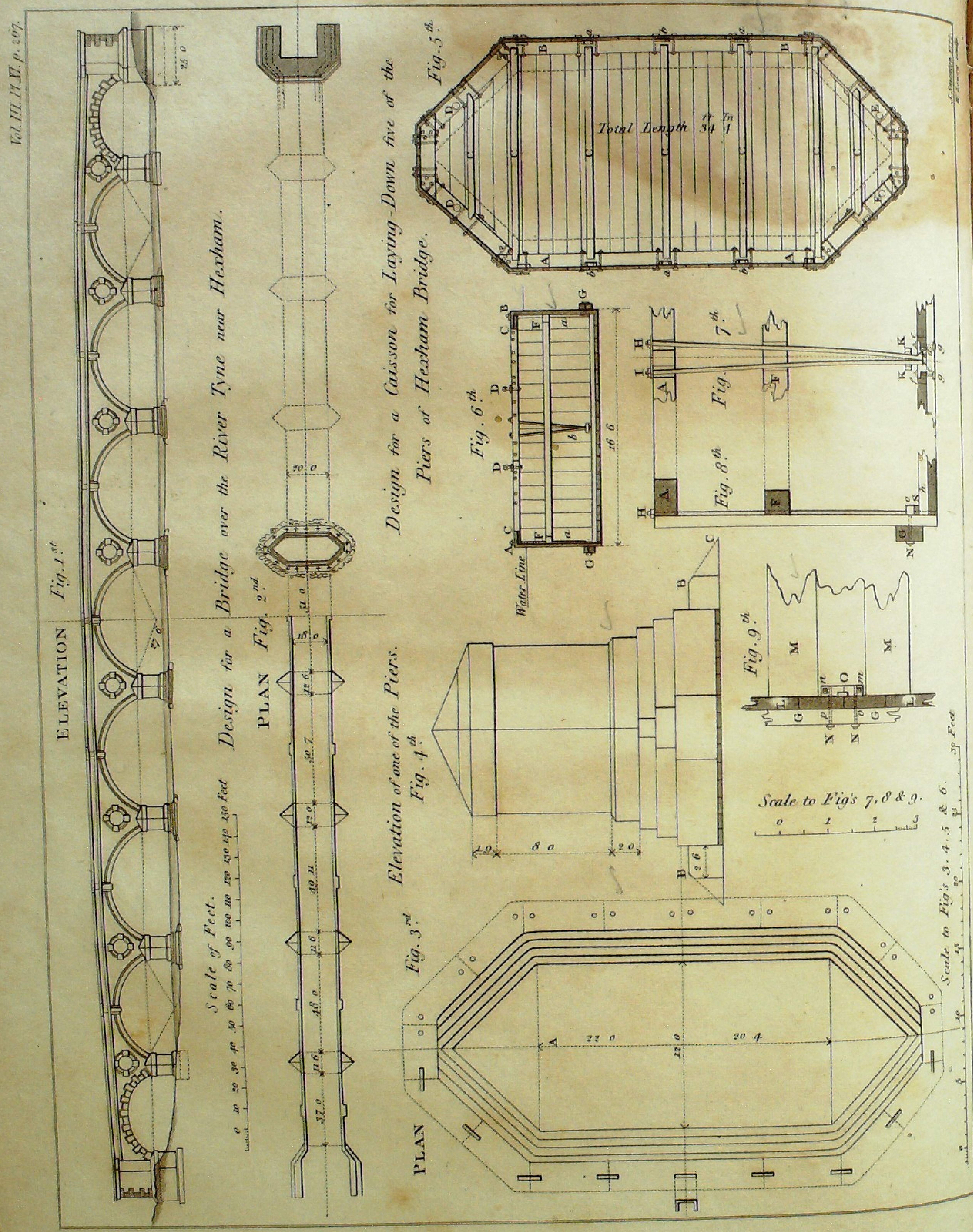
AN

AN Eſtimate of the expenſe of erecting a temporary bridge with fir-timber upon the piers or legs of the old bridge at Newcaſtle upon Tyne, 9th December 1771.

	£	s.	d.
14000 ſolid feet of fir-timber including the workmanſhip and ſcaffolding at 2s. per ſolid foot - - - - - -	1400	0	0
70 Cwt. of iron bolts and plates at 36s. per Cwt. - - -	126	0	0
80 Do. of Do. and piles ſhoes at 28s. per Cwt. - -	112	0	0
Walling up the South Pier of the remaining fourth arch from the Newcaſtle Shore, in order to ſupport the end of the temporary bridge, repairing the damaged ſterlings, rooming up the work for ſecurity during the execution, and covering the top of the bridge with gravel, computed - - - -	770	0	0
	£2408	0	0

Feet	Inches	
539	6	the length of the old bridge, from Quay to Quay.
330	0	the length of the temporary bridge.

N. B. Notwithſtanding this Report, the bridge was rebuilt in its old ſituation.



HEXHAM BRIDGE.

(See Plates 11, 12, 13.)

To Mr. Donkin,

Sir Austhorpe, 12 January 1777.

I BEG leave to acquaint you, that I have fully confidered the conftruction proper for a bridge over the river Tyne at Hexham, and have carefully computed every article of expenfe that will probably attend the erection of it in a fubftantial manner, and fufficient for me to rifk my credit as an artift upon it. The fituation is that which I particularly examined at the requeft of Mr. Errington, viz. about fifty yards below the boat, and nearly in a line with the little bridge that croffes the mill leet; in which cafe it will land at the north end upon the clofe eaft of the boat houfe, which is fituate between that and the lane.

The bridge I propofe to confift of nine arches, and to extend between the abutments 518 feet, and including the abutment well, 568 feet; to be twenty feet wide over all, and about eighteen feet between the parapets. I fuppofe it to be gravelled over in the manner of a good turnpike road, and the length of the road over the middle arch to be thirty-one feet above the furface of the river in its ordinary ftate: the height of the great inundation in the year 1771, being at this place above that furface fcarcely fourteen feet.

	£	s.	d.
The neat Eftimate of materials and workmanfhip - - - - -	6036	0	0
Upon the above, I allow 10 per cent. for engines, utenfils, and contingent expenfes	604	0	0
Expenfe of the bridge complete, with the road formed over it to the extent of the abutment walls - - - - - -	£6640	0	0
To forming the afcents to the bridge at each end, that at the fouth to be wharfed up with walls extending fifty yards with a breaft-work or rough parapet thereon, and fo that the flope fhall not be fteeper than one in twelve; mafonry, filling or forming the road to the extent of the flope - - - -	320	0	0
Total expenfe of the bridge complete, materials and workmanfhip - -	£6960	0	0

It

It is to be noted, that the road is supposed to be made up to the height of seven feet above the level of the ordinary surface of the river, and not higher.

It is further to be observed, that there is here no allowance for a small bridge over the mill leet; nor for forming the level road between that and the great bridge, nor for way leave or quarry leave, nor for the superintendance or surveyor's salary, which two last I cannot estimate at less than eight per cent. upon the above amounts, or at about 560l., making the whole sum 7520l.: so that, if Mr. Errington undertakes the bridge at a less sum than 7500l, with the intent of building it under my direction, it is probable he will be money out of pocket, and therefore lower than this I cannot advise his engaging therein.

I must observe, however, that the above is on supposition that every thing is to be provided, and therefore whatever the materials that are on hand may be found to be worth to this undertaking on a fair valuation, where they lie, will be so much to be deducted from the sum to be advanced by the country.

I cursorily viewed the situation opposite to the Hermitage, where I formerly proposed to build a bridge in 1756, and though I have no doubt of building a bridge there, yet to do it with a probability of safety against such a flood as that of 1771, which at that time was not thought of, is impossible there or in any other situation near Hexham, for less money than the amount of the above estimate.

I am, &c.

J. SMEATON.

To Mr. Pickernell. London, August 8th 1777.

DIRECTIONS for forming the elliptical arches and centers for Hexham Bridge.

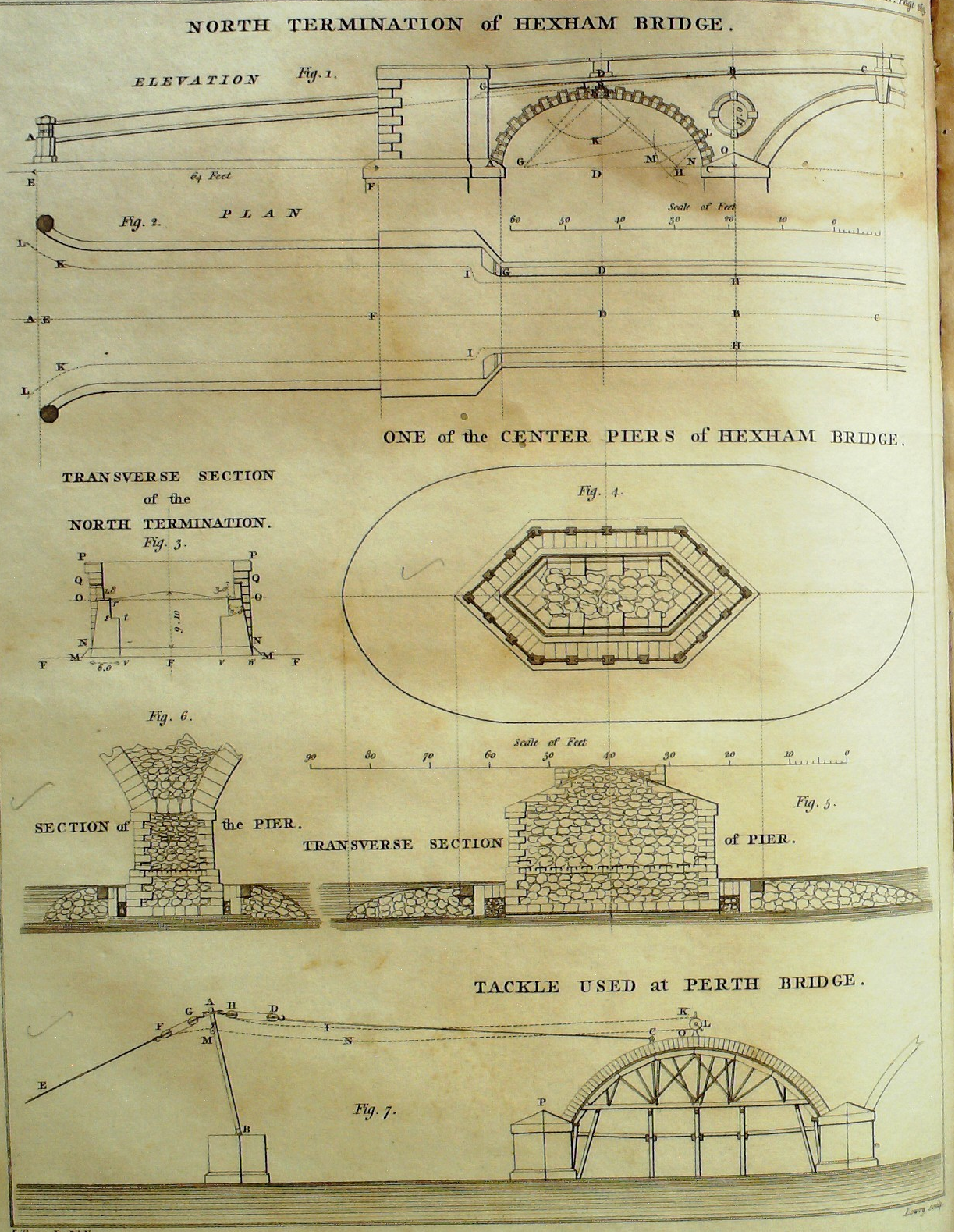
The true method of forming an ellipsis is by means of a trammel, with the construction of which I take it for granted you are well acquainted.

The dotted semi-ellipsis ABC (Plate 12, Fig 1.) is the medium line upon which the penstones are set out, by equal parts or divisions, and is 38 4 base, or width by 13 7 high, that is,

Ad—dC will be 19 2
dB . . . 13 7

Difference 5 7

and



J. Farey Jun.r delin.

Lowry sculp.

Published as the Act directs 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

and this difference of five feet seven inches will be the length of the crofs grooves, from the center to the ends, say five feet eight inches, to keep the pins from flipping out; and five feet seven inches will alfo be the diftance of the centers of the two pins that traverfe in the grooves; laying down therefore your crofs upon a floor, big enough to defcribe fomething more than half an arch, fet your tracing point at the diftance thirteen feet feven inches from the neareft traverfing pin, and with this you will defcribe the curve EBFLC at large; and if your ftones will run of twenty inches thicknefs, as drawn, fet off ten inches BE—BF, on each fide the center, and then divide the remainder FLC into 14 parts; but if your ftones will only run about 18 inches, then fet off nine inches on each fide B, dividing the curve FLC into 16 parts; if your ftones will hold but 15 inches, then fet off $7\frac{1}{2}$ or 8 inches for BE and BF, dividing the curve FLC into eighteen parts; and if they will not hold more than 14 inches, fet off feven on each fide, and divide into 20 parts. The points of divifion being thus fixed, fhorten the diftance between the tracing pin and the neareft traverfing pin, to 12 feet 11 inches, and then you will defcribe the interior curve to be of 37 feet fpan, and 12 feet 11 inches high; and if from this you fet out the tracing pin (pencil, or point) two feet, and three feet refpectively, you will then defcribe the curves that will take the extremities of the fhort and long ftones.

To find the directions of the joints, you take the line A d 19 feet 2 inches, and fetting one point in B with the other defcribe an arch, fo as to cut the line AC in G and in H, then will the two points G and H be the two foci of the ellipfis, which have this property; that if to any point of divifion of the curve as fuppofe L, you draw the lines GL and HL, then the line ML, bifecting the angle formed between the lines G and HL, will be the true direction or fummering of the joint at L, and fo of the reft. To avoid confufion, you have another example at the point I, the true fummering of which joint is K I. In this manner the joints of one half of the arch with the key-ftone, being neatly marked out upon the floor, and boards adapted thereto, (the grain of the wood correfponding with the length of the ftone), you will have a fet of molds by which all the ftones in the two arches may be hewn; but you are to obferve, the thicknefs of the penning within need not exceed the length of the fhorter ftones, the longer ones only appearing in front. You are alfo to obferve, that the arch like a femicircle, begins from an horizontal line NO, reprefenting the corner of the falient points of the pier rifing up before the arch ftone, or what may be better united therewith, by proper hewing, the ground joint being in the direction NC.

Refpecting

Refpecting the centers to the elliptical arches, the external curve will be ftruck out by the trammel, about two inches lefs than the fofit of the arch, to allow for the thicknefs of the boarding, and except the making of the curve quite fair, little curiofity otherwife will be required. I propofe nine of thefe ribs, and the curved part may either be fawn out of crooked wood, or lapped together from ftraight, according to the convenience of your materials. The curves may be about feven by $3\frac{1}{2}$, and bafe 10 or 12 inches by $3\frac{1}{2}$ or 4 thick; the ftandards may be made out of any offal ftuff you have, from $3\frac{1}{2}$ to 5 inches thick: in fhort the whole compofition needs not to exceed that of vault centering, when well and firmly done. The bafe may ftand on five bearings, one at each end, one in the middle, and one on each fide the middle, but fomewhat nearer the middle than the fides: perhaps it may be neceffary to put in an upright more in the ribs on each fide the middle one; for I would not have the fpaces near the middle to exceed $2\frac{1}{2}$ or 3 feet diftances at the top, middle and middle.

As the traverfing ruler will be required 20 feet long, and to have a confiderable degree of ftiffnefs edgeways, to prevent its being over bulky or clumfy, it may be proper to obferve that its greateft ftrength will be required at the middle pin, or the pin neareft the tracing point; you may therefore (making the whole $\frac{3}{4}$ thick) let the breadth at the middle pin be eight or nine inches; at the other traverfing pint about four inches, and at the end of the tracing point about three inches.

J. SMEATON.

To Mr. Pickernell.

Inclofed you have the defign for the caiffon, for the five piers of the bridge that remain to be laid, as alfo the defign and elevation for one of the center piers.

By "grooving in" of the fides, and crofs courfe of bottom planks, as expreffed in the explanation, I mean in the middle of the eye of each plank, like a common chamber floor grooved in with Dutch laths.

The reafon why I would have the infide blocks joint more clofe in the firft and fecond courfe than above is, that till the caiffon is fairly grounded, we fhall never be fure of keeping the joints whole; and as the fecond courfe will be fufficient to ground the pier, then all can be made good; and fo long as the upper parts reft upon folid guaged blocks, and then upon one another, it is not abfolutely material whether there were any fittings in the joints of thefe two bottom courfes or not.

J. SMEATON

EXPLANATION of the Defign for a Caiffon for laying down five Piers of Hexham Bridge.

Plate 11. Fig. 5. is the plan of the caiffon, being 16 feet within, by 22 feet length of the flat fide. The bottom is fuppofed to be made of three inch plank laid crofs and crofs; and the fides of three inch plank only, ftanding upright, and fupported by three ribs of wood, two upon the infide and one upon the out. The uppermoft AA, BB, to be ftrongly fecured with bolts and plates at the angles, and likewife fecured by bolts upon the fides, as fhewn in the plan. The pieces CC, &c. are ftretchers, but which being moveable, will not be in the way of lowering the ftones. The fides not refting upon the bottom as has been ufual, fo as to admit the ftone-work to be flufh with the bottom when the fides are removed; and thereby to let the girdle of large ftones flip down to their own bearing, without being interrupted by any projection, a particular method of faftening the bottom and fides is adapted to this purpofe, and the plates a, a, b, being 16 in number, each fhewing a double nut and bolt, fhew the places and difpofition of thofe faftenings.

DD, EE, fhew the places of iron ftuds, ftrongly fcrewed down, over which a chain being caft the caiffon is thereby moored to a large pile, to be driven at the diftance of 30 feet upftream of the bridge, before the point of each pier, to be kept fteady by another fmall pile, about as much below.

Fig. 6. is a tranfverfe fection of the caiffon, wherein is fhewn that the ground tier of planks in the bottom run lengthways; AB fhew the upper rib, the dotted lines CC fhew the ftretchers, DD the iron ftuds for mooring the caiffon, FF the middle rib infide, and the dotted lines fhew the moveable ftretchers of fix inches fquare, which, when the ftone-work is got that height, are to be removed, and the fides fupported by fhort ftuds againft the mafonry, if need be.

GG fhew the fection of the lower rib, which is put outfide, to prevent its interference with the ground courfe of ftone; this is four by eight; and as this and the middle ribs have no other ufe but to keep the upright planking fteady they need only be fpiked together; and on this account, if thefe ribs were of elm, or any other kind of wood than fir, they would be lefs apt to fplit by a multiplicity of fpikes; a a fhew two fets of the faftening bars feen fideways, and b fhews a fet feen in front; of which follows a more particular defcription.

Fig. 7. ſhews the upright of a pair of faſtening bars to a larger ſcale, as they would appear from without if the outſide planking was ſuppoſed to be removed or tranſparent; wherein A ſhews a part of the upper rib, F a part of the middle rib, and the dotted lines G ſhew the place of the bottom rib; c d e f ſhews a piece of caſt iron let down fluſh into the edge of the bottom, and which is held down by the two bolts gg. This piece of caſt iron contains a dove-tail notch, in which h H is the dove-tail bar; and thereby ſuſpending the bottom upon the nut H; to which i I is the bar compoſing the key, which is to be driven in; but by turning the nut I will draw it out, and releaſe the other, and by the ſame means all the faſtenings in like manner being ſlacked, the ſides of the caiſſon will be releaſed from the bottom. KK is a ſtaple whoſe uſe will be ſhewn hereafter. But as it will be neceſſary that the ſides of the caiſſon ſhould be under ſome confinement towards the bottom to preſerve a water-tight joint between them,

Fig. 9. is a plan of a part of the bottom, wherein LL repreſent the ſide planking, GG the lower rib on the outſide, and MM the croſs planking of the bottom. Now m n o p is the plan of the caſt-iron dove-tail notch piece; which notch being dove-tailed with reſpect to its plan, as ſeen here, as well as with reſpect to its upright, ſeen in fig. 7, and the bars being adapted thereto; by this means the bars will be confined from flying out ſideways, as well as from drawing; and the ſtaple ONN, ſhewn by dotted lines paſſing through the bottom rib, being tightened by the nuts NN, will draw and confine home the ſides to the bottom; there is yet another thing wanting, and that is, that there being nothing to confine the ſides from going below the bottom, there will be ſomething neceſſary to counteract the nut H, fig. 7; now fig. 8, is an enlarged ſide view or ſection of the ſide of the caiſſon and bars, wherein the ſame letters denote the ſame things as the preceding, and the bar h H is ſuppoſed to be the ſame bar as marked with thoſe letters fig. 7; now, if between the under ſide of the ſtaple and the caſt metal notch piece there be driven an iron key a little wedge-wiſe, whoſe ſection is repreſented by the little ſhaded part at S, the ſide can be ſo regulated as not to go below the bottom, and ſo as to keep every thing ſufficiently ſteady; nor is any degree of ſtrength in this matter neceſſary, as the weight of ſtone in the caiſſon, when afloat, does not in reality hang by the faſtenings, but is ſupported by the counter preſſure of the water under it upwards.

As the bottom courſe of ſtone is to be cloſe home to the ſides of the caiſſon, grooves muſt be cut in the ſtones where they come againſt the faſtenings, with full liberty to draw them out.

The

The notch pieces neceſſarily go along with the bottom, but one ſet of faſtenings will do for all; and it will be proper to have the dovetail part of the bars well fitted to the notches with a file; care being taken to have the notches caſt ſo near alike that fitting one they will fit all.

Though it is not mentioned in the deſcription, it will be proper that all the joints of the planking and the ſides, and the croſs or upper planking of the bottom, be grooved in about three-fourths of an inch in depth; and a lath one and a half inch broad, and about three-fourths or one-half inch thick inſerted, and let in with tar, that the pinning of the joints by drought may not induce the neceſſity of caulking; and to ſecure the joint between the bottom and ſides it will be proper to nail on a ſtripe of thick flannel and tar three inches breadth upon the out edge of the upper tier of floor planking, and this joint may be further ſecured, if ſeen neceſſary, by a ſlight caulking inſide.

Fig. 3. ſhews the plan, and fig. 4. the elevation of one of the middle piers, with the plan and ſection of the girdle of the ſtone round the baſe. The baſement of the pier is ſuppoſed to conſiſt of two courſes of ſtone, both of which are to be made entirely of blocks; the interior blocks need not, however, be jointed as to their upright, or ſcrupulouſly fitted to each other, but to be brought to a thickneſs anſwerable to the courſe, and to be ſet upon their bigger bed as cloſe to one another as may be, and the interſtices carefully filled, and walled with beſt mortar.

The two upper courſes reaching to the low-water level muſt alſo be interſperſed with blocks gauged to a thickneſs, but need not be ſo cloſe to each other as deſcribed for the two ground courſes; if in theſe upper courſes the gauged blocks occupy two-thirds of the ſolid within the outſide courſe it will be ſufficient. The firſt courſe of the baſe or chamfered plinth being above water is to have three chain courſes go acroſs it, that is three rows of blocks, one acroſs the middle and one near each ſhoulder, to be ſtrongly cramped together, and to the ſtones in the outſide courſe, or joined by one continued bar acroſs; and all the outſide ſtones in the circumference of the chamfered courſe to be joined by one continued chain bar. In other reſpects, the maſonry above the low-water line to be compoſed in the ſame way as the piers already executed above that line.

N. B. The ſhoulder angle of the girdle courſe, and of all the other courſes under water is centered at A, in the plan, and the dotted line in the upright, denotes a ſlope of rock-work formed by a depoſition of rubble, ſtone, and cement, called beton.

J. SMEATON.

Auſthorpe,
17th Dec. 1777.

From

From Mr. Pickernell. Hexham Bridge Office, July 2[illegible] 1778.

I can now give you a particular account of the damage we have received from the high water, which came on us laſt Tueſday night and Wedneſday morning.

The pier which I laſt founded at the ſouth ſide is undermined at the weſt point, and ſettled down conſiderably. I meaſured the water and found the gravel to be taken away about 18 inches below the bottom of the caiſſon. The foundation of the fourth pier from the ſouth abutment is taken out at the ſouth end, and nearly half along the pier, ſo as to let the weſt point, or cut-water, ſettle about 18 inches. The gravel is taken out in ſome parts, as nearly as I can find, two feet ſix inches lower than it was when the beton was laid on the bed of the river, and ſeveral ſtones are taken out of the cut-water part of the pier. The water came with ſuch velocity as to undermine the girdle-ſtones, and force up betwixt them and the pier ſo as to force the girdle-ſtones two feet from the pier. In ſome parts the iron cramps which were laid into the baſe courſes have confined that part together, or elſe, I believe, all the cut-water part of the pier would have been entirely ſwept away by the violence of the ſtream. Though the water was not very high, I never ſaw it ſo ſtrong.

I cannot ſee that the fourth pier from the north has received any damage, except that the bed of the river round the ſinking ſtones at the weſt end of the pier is in part taken away; though, I believe, had it been as high as the other it muſt have ſuffered the ſame fate. The third foundation from the north abutment has ſuffered the ſame as the ſecond from the ſouth abutment. The gravel is taken out from under the weſt cut-water about 18 inches, and the point is ſettled down. Indeed I had not the good fortune to have the girdle courſe laid round the weſt part of the two foundations, as we could not get them at the quarry faſt enough. None of the foundations which were laid laſt ſeaſon have received any damage.

I am, &c.

J. PICKERNELL.

To Mr. Donkin. Auſthorpe, 29th July 1788.

I have received a particular account from Mr. Pickernell of our very diſagreeable misfortune, and find it no ways more flattering than I had reaſon to expect from the contents of your letter. What I moſt blame myſelf for is, in not ordering every pier to be ſecured, not only with the girdle courſe complete, but with the ſlopes of rubble ſtones brought up againſt it, before another pier was laid on the bed of the river; becauſe notwithſtanding what has happened, had the foundations been ſecured, and finiſhed on

in the manner I had intended and propoſed, before winter, I am fully ſatisfied this diſaſter would not have happened. As it was, I was willing to puſh on the work in the prime of the ſeaſon, and confiding in the natural ſtrength and compactneſs of the gravel bottom, I could not have ſuppoſed ſo much derangement would have happened in the courſe of two or three ſummer freſhes. I hope I ſhall not find matters irretrievable.

DIRECTIONS for ſecuring and repairing the under-waſhed Piers at Hexham Bridge.

NOTWITHSTANDING the natural hardneſs of the upper cruſt of the gravel bottom, it being now found not capable of reſiſting the action of the water in ſudden and rapid floods, it appears neceſſary to incloſe the ſeveral foundations by a fence, or caſe of ſheet piling, to prevent, at all extremities, the gravel from waſhing from under the baſes of the piers; a plan for the doing whereof accompanies theſe directions.

The work may be begun upon any of the piers that are found convenient, and as ſoon as may be, the bays compoſing the two ſheets that form the ſalient point before the weſt end of each pier ought to be completed, together with one bay of the return upon each ſide of the pier; and as ſoon as this is done the cavity waſhed below the bed of the river ſhould be filled up rather higher than the original bed of the river both inſide and out. The outſide to be filled with rough rubble ſtones from the upper bed of Oakwood Bank quarry, which are exceedingly well adapted for this purpoſe, to be of promiſcuous ſizes, the largeſt not exceeding half a cube foot, or about 70lb. weight. The inſide to be filled with the ſame kind of quarry rubble of promiſcuous ſizes, the largeſt not to exceed that of a large double fiſt, or about 12lb. weight, and for every two buſhels or meaſures of rubble uſed within the caſe one buſhel of clean ſand muſt be thrown upon them.

This done, the deſirable thing would be to proceed thus far with all the four piers that have been laid down in caiſſons, by which means all the piers will be guarded from further damage, after which the completion of the caſing can be done more at leiſure, nor ought this to be omitted with reſpect to the north pier of the center arch, which, though it has ſuffered no material derangement from the late floods, yet experience ſhewing that the gravel bottom ought not to be truſted, the ſame means ſhould be applied as a guard to its ſafety as to the reſt. However, if the piling is found to go on

with readineſs and facility, and the moving of the tackle from pier to pier a work of labour, then, at the diſcretion of the ſurveyor, the piers may in turn be ſurrounded wholly before the tackle is moved.

As ſoon as the gage piles are driven, the ſcrew clamp may be applied upon the ſurface of the water; or indeed if the piling of each pier be gone on without removal, this clamp may originally be applied as an outward frame for directing the driving of the gage piles, and for retaining them in their places while the ſheet piles are driven; and for greater facility, certainty, and exactneſs, in driving the ſheet piling, ſo as to render them water-tight, I would recommend the long ſides to be divided into four bays, and the ſalient point ſides into three each.

When the caſe is completed, reaching above low-water, it may be tried whether the water can eaſily be got out, and if ſo, the under pinning, where wanted round the ſkirts of the caiſſon bottom, may be done by men's hands; but if not, the whole of the interſtice between the caſe and the pier muſt be ſitted with rubble and ſand, as before directed for the weſt ends, about ſix or eight inches higher than the bottom of the caiſſon, and afterward driven down by a ſett of about one foot ſquare at the lower end, acted upon by one of the hand-rams: this will cauſe the matter to ſpread under the ſkirts of the caiſſon bottom, and the caſe hindering it from ſpreading outward will render all tight and firm. This done, the interſpace between the caſe and the ſides of the pier muſt be chocked in with blocks of the thickneſs propoſed for the girdle or ſunken courſe, which being ſcappelled to a tolerable ſquare, and adapted to their places, they will not need cramping; but yet, to prevent any violent flood from turning any of them out of their places, it muſt be obſerved to chamfer the upper or leading edge of each croſs joint, as ſhewn in a detached figure, as alſo to pin them faſt with wedges, ſtones, and pebble mortar, or beton, which may be eaſily done if the caſe can be drained, as I expect it may, ſo as to dry the upper ſurface of the ſunken courſe. This being done, the whole of the caſing is to be driven down with ſetts, or otherwiſe cut off to the level of the ſunken courſe, and the ſcrew clamp ultimately fixed, ſo as to be rather below the tops of the piles, which will effectually confine all cloſe home together.

The work being thus fixed, the outſide of the caſe is to be guarded with a ſlope of rubble, which, that it may be the better grounded by a competent body of matter, it will be adviſeable firſt to let the work ſtand the effect of a flood; and then not only filling up the excavation that may be expected on the outſide of the caſes, up to the general level of the bed of the river, but forming a ſlope extending to the diſtance of about ſix feet upon the baſe, at the height of

of the bed of the river, and to reach as high as the clamp. After this, the ſlopes muſt be examined at every flood, and ſupplied where found deficient till the matter appears to be at reſt, which ſooner or later will be the caſe, when the river hath formed itſelf ſuch a channel between the piers as is natural to the new ſett of the ſtream, that the interpoſition of the piers of the bridge muſt neceſſarily occaſion.

In caſe by repeated floods while the work is going on, any of the foundations ſhall appear to underwaſh more than they have done, it will be proper to throw round the weſt end and weſt ſhoulder of ſuch pier a competent body of rubble, the largeſt not weighing more than 25 or 30lb.; for through rubble of this ſize piles may afterwards be driven nearly as well as through large gravel.

The length of the piles ſhould conform to the depth of the water. I would not wiſh the ſheeting piles round the weſt end and firſt bay of the return on each ſide to go into the ground more than about ten feet; and if they do not drive kindly, muſt be contented with leſs; from thence each bay may be gradually leſs depth into the ground, ſo that round the down ſtream pointing ſeven feet will be ſufficient.

If the gage piles drive more kindly, they may be longer by 18 inches or two feet than the ſheeting; but if not, they need not be above one foot longer: and to make them drive kindly, as well as fix faſter, it will be proper to point them longer than heretofore, that is, to about three feet, but not ſhouldering, as with a regular taper, but curved, beginning from nothing at three feet.

The length of the piles covering the weſt end and returns of the fifth pier from the north, being that moſt underwaſhed, the ſheet piles ſhould be at leaſt 15 feet long, and the gage piles in proportion, and the reſt proportionable to the depth of the water; and reſpecting this pier, as the lowering of the water in the caſe will be more neceſſary than in the reſt, it will be proper before any rubble is put in outſide the caſe, to put a layer of earth or loam upon the bottom, amounting to about ſix inches thickneſs, that is, allow a cube yard to ſix yards ſuperficial, this will choak up the pores of the gravel in the deep places, and retard the percolation of the water through the gravel, ſo as to give a better chance of getting out the water, for new founding the weſt end, if deemed neceſſary.

What regards the repairs of the maſonry I ſhall defer to a future opportunity of delivering, in due time.

It

It will be proper, in driving the gage piles, to try to ufe the great ram, fitted with a moveable difcharger, fo as not to be lifted above fix or eight feet above the pile heads; by which means I apprehend it will be found to drive the piles much more kindly than if lifted its full height, and perhaps more kindly than the hand ram.

J. SMEATON.

Hexham,
5th *Auguft*, 1778.

Additional Inftructions.

When the caiffon bottom is fully underpinned, according to the method defcribed, let the point be taken down one courfe as far as the fhoulder, fubftituting other ftones of fuperior thicknefs, fo as to raife the point rather higher than it was originally, by 1½ or 2 inches; reconciling, however, the new with the old work at top, and cramping every ftone to its neighbour, and to the block ftones of the old work, with common mafon cramps, run in with lead at each end, to bring them to a bearing, or otherwife fixing them faft with wedges. If you fhould have any difficulty to get them dry enough to run in the lead, heating the cramp, and putting a little oil into the holes, will render the difficulty lefs.

The taking up one courfe will do for the third and feventh piers; but for the fifth you may take down and cramp as before directed, as far as you can.

I have alfo confidered, that if you can but get large ftones for the up-ftream pointings of the girdle courfe, or funken courfe, the reft may be done with aifler, whofe breadth and length is fufficient; and if you can get the water off, as I expect you will, fo as to point and fill with the very beft mortar, which when ftruck to a breadth will make the open joint upward, and more capable of being filled. I would not, however, have any thing pointed from the down ftream fhoulders to the down ftream point; only chocked faft with ftones or wedges, leaving interftices there for what water may get in at the up ftream part of the pier, to make its efcape freely below. Such of the old aiflers as will anfwer to the length and breadth will effectually ferve the purpofe without any new dreffing.

J. SMEATON.

9th *Auguft* 1779.

EXPLANATION of the Defigns for the Diving Machine for Hexham Bridge.

(See Plate 13.)

To Mr. Pickernell.

Sir,

Aufthorpe, 16th September 1778.

IF the cafes would have enabled us to reduce the water fo low as to be even with the very bottoms of the caiffons of each pier, I take for granted you would have thought it no difficulty with broken rubble, beton, ftones, and fhort blocks of wood cut a little wedgeways, to have crammed and wedged full the cavity underwafhed, under the wooden bottoms; fo as to have been equally refifting, and capable of bearing a weight with the original gravel, and particularly when this new body of matter is fupported, and even jambed tighter into its place, by filling up the vacancy between the pier and the cafe, a little above the wooden bottom with rubble, and then driving it tight down by a fett with the ram. It therefore now remains, that I defcribe, and make you mafter of a piece of machinery, that will put you nearly into the fame condition, as if the water could have been reduced to the caiffon's bottoms as before mentioned; and this is by means of an air cheft or diving veffel, which being let down will exclude the water down to the very bottom of the river, if you pleafe; and therefore as low as the underfide of the wooden bottom, which in the prefent cafe is as low as will be neceffary or ufeful; and the cheft or veffel being large enough to give liberty for a man to work therein; being furnifhed with a pair of boots, he will at mid-leg deep in water, do his bufinefs with almoft as much facility as if the water were pumped out to the fame level.

The principal part of this machine will confift of a ftrong cheft, fuppofe three feet fix inches in length, about four and a half feet depth or height, and as wide as to give free leave for its going down between the cafes and the piers, which I fuppofe will be about two feet wide infide meafure, as the other meafures are alfo fuppofed to be. Now you know very well, that if you pufh a drinking glafs, or any other fimilar veffel with its mouth downwards into the water; that it will exclude the water, leaving the veffel full of air, as it was before it was thruft into the water; in like manner, if this cheft, being loaded with a fufficient weight, be let down into the water mouth downwards, the air will exclude the water to the bottom fkirt of the cheft, and if let down fo as to reft upon the bottom of the river, a man may ftand dry therein, and do any kind of bufinefs, the fame as he could do in the fame fpace in the open air. But to continue this for any length of time, two things are obvioufly neceffary, and thofe are light, and a circulation of frefh air. The former might on occafion be fupplied by a candle; but here we may have the advantage of

of day-light, by putting in two or three ſtrong round panes of glaſs into the bottom of the cheſt, which will in its inverted ſituation in uſe be the top; a ſufficiency of light will enter, this top of the cheſt being ſuppoſed above water.

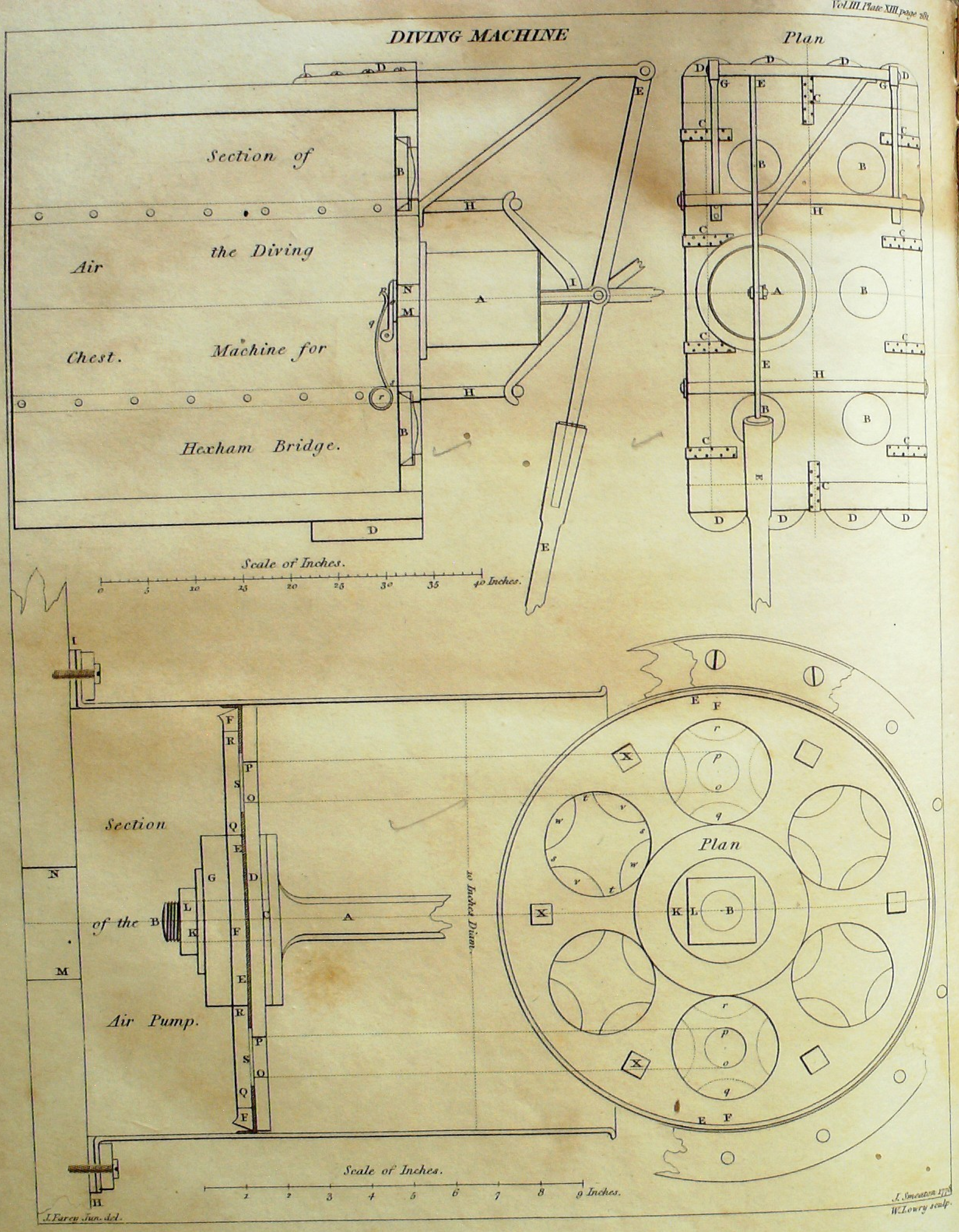
Reſpecting air, you will conceive that any quantity might be forced in by a ſtrong pair of bellows; but theſe made of leather, would be cumberſome and unhandy. I therefore ſubſtitute a kind of forcing air-pump, made of thin hammered copper, that will throw in a gallon at a ſtroke; which will not only continually refreſh the workman within, but whatever air eſcapes out through the joints or pores of the air-cheſt, will be repleniſhed, and the overplus go out at the bottom or ſkirt of the cheſt, and boil up on the outſide.

The quantity of weight that will ſink it mouth downwards, will be the ſame as placed therein (bottom downward) would ſink it the ſame depth, and as this cheſt I propoſe to be ſuſpended by a tackle, and to go down by its own weight, I compute that it will take 16 pigs of lead to ſink it to the bottom of the river, and keep it ſteady; I propoſe that the lead may be as much out of the way as poſſible, to place them upon the ends of the cheſt, endways upward, that is, four in a row below, and four above, and the ſame at the other end; making in the whole 16 pigs, which are to be faſtened on with ſcrews, either by cleats ſcrewed on, or punching a hole through each end of each pig.

At one end of the cheſt there is to be a board fixed acroſs for the man to ſit upon, and a cleat nailed on each ſide, to ſet each of his feet upon, ſo that while the machine is letting down or hoiſting, he is totally dry, and when let down low enough, he ſtands upon the bottom of the river, without any more water than the height between the ſkirt of the cheſt, and the bottom of the river, which may be more or leſs as is found convenient, I ſuppoſe never more than a foot deep; becauſe wherever the ground is taken out more than one foot below the under-ſide of the caiſſon's bottom, I would propoſe to fill it up with rubble previouſly to that height or depth; nor can it be of uſe to let down the ſkirt of the cheſt much below the caiſſon bottom, becauſe the ſide of the cheſt will then diminiſh the room you will have, to get the matter for underpinning under the caiſſon bottom.

The foregoing will I believe be ſufficient for explaining the general principles and outlines of the method I mean to purſue in underpinning, and re-ſupplying what is underwaſhed from the baſes of the piers, and which I dare ſay you will now ſee to be entirely practicable.

What



Published as the Act directs, 1812, by Longman, Hurst, Rees, Orme and Brown, Paternoster Row, London.

What you are therefore immediately to put in hand, is the air-cheſt, of or about the inſide dimenſions before mentioned; I believe the two flat ſides will do very well, if of good red wood deal ſhot clean of ſap, the two ends and bottom (or in *uſe* its *top*), it would be well if they could be got of ſingle planks of elm, beach, or plain tree, as they would hold the nails better; I fancy 1½, or 1¾ thick for the ſides, and 2¼ or 2½ for the ends and bottom, will be ſufficient; they ſhould be well jointed, and put together with white lead and oil, and the inſide joints ſtroked with white lead and oil, as the effort will not be of the water to enter, but of the air to eſcape from within.

Were I with you when it is put in uſe, I ſhould be the firſt to go down in it, as there is no more danger (all your tackle being firmly fixed,) than being let down into a coal pit by a rope; and if it ſhall happen that all your maſons are too fine fingered, I fancy a couple of colliers to take turn and turn, will find it a very comfortable job; a particular encouragement muſt however I expect be given.

I will give you more particular directions in my next: as to the air-pump, all that will be wanted from the copper-ſmith will be a cylindrical pipe of copper, 10 inches diameter and 12 inches high, wired at top, and a flanch at bottom of about 1¼ inch broad, by which it is ſcrewed down upon the top of the air-cheſt; the copper to be about the thickneſs of a halfpenny; if you have no neat handed copper-ſmith, that can hammer it ſtraight and ſmooth inſide, it may on occaſion be made of ſtrong tin.

I am, Sir, your moſt humble ſervant,

J. SMEATON.

The materials will be got into the cheſt by letting them down in a ſhallow bucket or box, that will go under the ſkirt of the air-cheſt; which ſhould be let down upon blocks to keep it ſteady, while the air pump is worked; you will do well to try it, firſt in ſhallow water, and deeper by degrees, from whence you will find the nature of its working.

Explanation of the Section of the Air Pump, Plate 13.

A—The piſton ſhank and flanch terminating in

B—A ſcrew by which the whole is compreſſed together.

C—Leather to keep the joint air tight.

D—The

D—The upper plate (to be made of boiler plate), $\frac{1}{10}$ inch leſs in diameter than the copper barrel.

E—A flat middling piece of ſhoe upper leather, turned down upon the border to make a tight joint with the barrel, and which alſo compoſes the valves.

F—The under plate (alſo of boiler plate), the edge being a little raiſed round the border, and about $\frac{2}{10}$ leſs than the barrel: the leather D being held tight between theſe two plates.

G—A piece of wood by way of butt or ſtop upon

HI—The upper ſurface of the plank of the air-cheſt's bottom, in its inverted ſituation.

K—An iron ring, and

L—The nut that fixes all faſt.

MN—The opening through the plank, by which the air paſſes into the cheſt, and is ſhut by a valve or clack on the underſide.

OP—Shews the opening through the upper plate.

QR—Ditto through the lower plate.

S—The ſolid part of the leather that ſhuts the hole OP when the piſton is forced down, and gives leave, by means of its four arms, for the air to enter when it is drawn up.

Explanation of the Plan of the Air Pump.

FF—Shews the under plate, and under face of the piſton.

EE—The leather.

q r—The holes through the ſame.

o p—The holes through the upper plate, as they would appear if the leather were removed.

At *s t*, *s t*, the leather appears in place; and *v w*, *v w*, thoſe ſpaces being cut away, give leave for the air to paſs in going downward from above, while the piſton is aſcending; but not to eſcape from below upward, while the piſton is forced down.

N. B. the reſt of the letters marked upon the plan refer to the ſame things as the ſame letters refer to in the ſection.

XX—Shew the ſquare heads of ſmall ſcrews tapped into the oppoſite plate, in order to hold the plates cloſe together near the border, as the nutt and ſcrew do in the middle: the heads, however, will be better above.

Explanation of the Plan of the Air Cheſt.

A—The air-pump.

B—The ſky lights 6 inches diameter each, to be made of window glaſs knobbs, if plate glaſs is not to be had.

C—Clamp plates of iron to confine the top and ſides ſtrongly together.

DD—Pigs of lead, end upward.

EE—The lever for working the pump.

GG—The axis and brace for ſteadying the lever.

HH—Two bows for hoiſting the cheſt.

Explanation of the Section of the Air Cheſt.

The ſame letters referring to the ſame things as in the plan.

I—A ſtrong crooked iron to lay hold of the bows to which the main rope or tackle is to be fixed.

MN—The opening from the pump to the air cheſt.

o p—The valve; whereof *o* is leather, *p* wood; to be ſhut by a wire ſpring, *q r s*, a little more than ſufficient to overcome the weight of the valve.

To Mr. Pickernell.

Sir, London, 1ſt April, 1779.

As I look upon it that the judiciouſly ſetting on of the baſe courſes upon the damaged foundations is a very material point of conſideration, it was for this reaſon that I was willing to take the whole of the winter fully to make up my mind about it; and having now ſeen the firſt of April, I ſhall no longer defer ſetting you at liberty.

You will readily comprehend, that if, inſtead of beginning with maſonry from the bottom, two or three large detached pieces of rocks had been depoſited in the river, of a ſufficient ſize to build our piers upon; theſe ſerving as feet to ſtand upon, and each capable of ſupporting a proportion of the weight: thoſe rocks, though unconnected below, yet if they are firmly connected at and above the ſurface of the water, by a cap of ſtone well cramped and united in one; this cap would ſerve as a new baſement that could not ſeparate, whereon to raiſe the reſt of the ſuperſtructure.

Our piers in ſome degree anſwer the above idea; and it will now be our buſineſs to make a cap of the two baſement courſes, bonded together with a degree of firmneſs that would not have been neceſſary, had no derangement ever happened.

I propoſe, therefore, that the two baſement courſes be filled in with block ſtones, gauged to a proper thickneſs in reſpect to their beds; and ſo far ſtruck off upon their ſides, as to give opportunity to cramp them to one another, both inſide and out. The outſide ſtones I would adviſe to be cramped to one another with cramps from $1\frac{3}{4}$ to 2 inches broad, and from $\frac{5}{16}$ to $\frac{3}{8}$ thick, all well leaded in, and of ſufficient length to get at leaſt ſix inches fair hold of each ſtone. The whole to be bedded and worked in with terras mortar, of which I will give you the compoſition.

In the next place, as the ground could not be conſolidated with piles under the firſt foundations, I always expected theſe to ſettle to the value of an inch more than the piers that have piles underneath them; but as in conſequence of our derangements, our bearings will be rendered in ſome degree unequal, a greater ſettlement may be expected to take place at the weſt, than at the eaſt end; for theſe reaſons I would have the baſement courſes ſo ſuited to the preſent work, that the eaſt end of the baſement ſhall finiſh an inch higher than the finiſhed piers; and the weſt end two inches higher; alſo that the weſt point and ſhoulders be carried $1\frac{1}{2}$ inch further weſt than the finiſhed piers, ſo as to make the piers $1\frac{1}{2}$ inch longer than the former. In raiſing the ſhafts, I would gradually loſe this $1\frac{1}{2}$ inch in getting up to the impoſt, by ſetting on about the value of $\frac{1}{8}$ of an inch at each courſe;

courſe; ſo that the impoſt will be of the ſame length as the former, but ſtill finiſhed one inch higher at the eaſt, and two inches higher at the weſt ends. Now if afterwards the weight of the arches and ſuperincumbent matter ſhould not preſs down the piers in the proportion allowed for, this will make no apparent fault; becauſe it will rather give addition of elevation to the middle of the bridge; and if the ſettlement ſhould be double to what is allowed for, which I think is as much as can poſſibly be expected, it will ſtill be ſcarcely viſible. The main thing, therefore, that we have to guard againſt in carrying up our piers, is to do them with that care and ſolidity, that though the bearings may be ſomewhat unequal, yet that the whole may go together, without ſhewing any ſetts or rends in the outſide aiſler; and which, though it may happen without any material detriment to the real ſolidity and duration of the work, yet it will diſgrace our building in the eyes of thoſe very many (in proportion to the whole) who can neither ſee nor reaſon any further; on which account I would conſtantly keep the weſt end ſome courſes higher than the reſt, building up as it were a head, and making off the courſes. I would alſo cramp every courſe in the outſide aiſler, from the weſt point to half-way down the long ſides, and every other courſe down to the eaſt ſhoulders, till you come to the next courſe below the impoſt; at which height I would throw three block or chain courſes acroſs, in the manner I formerly ordered; there let the work of each pier ſtand as long as we can, and afterwards finiſh as has been already done. I mean what relates to the cramping above the baſement to regard chiefly the third and ſeventh piers: as to the fourth, after the cap is on, as before, I think it will be ſufficient to cramp every other courſe from the point to half-way down the ſides only; but in regard to the croſs chain courſes at the height above mentioned, no caiſſon pier ſhould want them. In regard to the fifth, I muſt ſuſpend all directions till I ſee how it is likely to turn out.

The place where I am moſt apprehenſive that ſetts may appear, is about a yard below or down ſtream of the weſt ſhoulders. I would therefore have you avoid putting in long ſtones faceways, near thoſe parts; for though this may cauſe a few more cramps, and in common apprehenſion not be ſo ſtrong: yet, as every joint will give way a little, it will prevent the breaking of the ſtones in the middle, nor will the weight above act by ſuch long levers to break them.

Inſtead of our former terras mortar, take as follows:

Common lime 1, barrow lime 1, terras $\frac{1}{2}$, ſand $1\frac{1}{2}$; — this doſe with pebbles what you can, for rough work.

To

To ſet ſtones under water:

Barrow lime 1, terras 1, very ſmall pebbles 1; — this being very well beaten, and let grow rather ſtiff, put it down in lumps about the ſize of a pullett's egg. If you have an opportunity of flat bearings, you may mortar the under ſide of the ſtone to be let down.

Below you have my deſcription and directions concerning the new tackles.

I am, &c.

J. SMEATON.

DESCRIPTION of the Shears and Tackle that were made Uſe of in raiſing the Piers, &c. of the Bridge of Perth, and recommended for Uſe in Hexham Bridge.

(See plate 12. fig. 7.)

AB ſhews one of the ſhear logs, which are framed into a ſoal piece being of nearly the ſame height and ſcantling as the ſhears, that is, about ſix inches, but inſtead of being fixed by back ſtays, they are made to overſet by guide ropes commanded by tackle blocks in the following manner:

The guide rope CD is ſuppoſed to be fixed to a lewis to ſome part of the adjacent pier or arch; the guide rope goes to an adjacent pier if raiſed to its height, or the next but one, if the next is not raiſed much above water. DH are a pair of blocks with two ſheaves each, whoſe fall HIK goes to the jack roll or windleſs L, mounted upon a frame in the uſual manner, and fixed upon ſome convenient part of the adjacent pier or arch: now as the roll drawing by the fall KIH, tends to draw the ſhears towards it, with a power of one excluſive of the purchaſe of the tackle, and as beſides the fall there will be four parts of the rope acting as a purchaſe, the conſequence will be, that the whole purchaſe will be as five to one, and the roll muſt gather up five yards of tackle fall to make the blocks DH advance one yard towards each other.

Again,

Again, the tackle blocks F will tend to draw the ſhears the contrary way to the other, and the tackle fall FMNO being attached to the under ſide of the roll L, this roller will command the ſhears either way by turning it one way or the other; now to keep the two tackle falls thus brought to the roller at any equal tightneſs, or nearly ſo, it is neceſſary that the two purchaſes may be equal; it therefore appears that if the fall ONMF, acting over the ſingle pulley M, which ſerves only as a director, were ſimply attached to the block F, no power this way applied to the roll at L, would produce any action upon the ſhears, but only pull at the fixed part of the guide rope EF without producing any action any where. The blocks FG, therefore, muſt contain a purchaſe of five, and this will be done by making the block F treble, and the block G double, the ſtanding part being fixed to the block G, in like manner as the other ſtanding part will be fixed to the block H. If, therefore, one fall is attached to one end of the roll, and the other to the other, while one is winding off, the other winding on, four feet in length, and ſix inches in diameter will be fully ſufficient; and the handle being of the ſame length as before preſcribed, as one man will generally manage the matter, the handles will beſt be ſet oppoſite that they may ſimply balance each other.

To avoid all confuſion of the figures, I have wholly omitted the main tackle blocks, which are ſuſpended from the top of the ſhears; and to avoid the platform of the work from being crowded, I ſuppoſe the fall for the main tackle to be returned from a ſnatch block fixed to a lewis, next the foot of one of the ſhear logs, and from thence paſſed to a main windlaſs or jack roll, and ſuppoſed to be placed upon the adjacent pier at P, or upon the arch near the other windlaſs. Two men in ordinary caſes being ſuppoſed to manage both windlaſſes, that is to aſſiſt each other in hoiſting the ſtone perpendicularly, and then one of them to go to the guide tackle windlaſs to overſet the ſhears, which done, the firſt can lower it by the main tackle.

The overlaying of the ſhears ſhould be ſufficient to clear the ſtones from rubbing and beating againſt the ſides of the pier, while hoiſting perpendicularly, and the feet of the ſhears may either ſtand upon the aiſler or juſt behind it, ſo as to drop ſuch ſtones into their places as come within their compaſs, and that on either ſide. The fall of the main tackle may be prevented from dipping in the water, in paſſing from pier to pier, by a ſmall block being ſuſpended from the guide rope at I.

The guide tackle blocks may be ſuch as thoſe made for ſhipping, the ſheaves about ſix or ſeven inches.

J. SMEATON.

London,
27th *March* 1779.

To

To Mr. Pickernell. Austhorpe, 25th Feb. 1780.

I have made up my mind respecting the north termination which I now enclose, and expect you will find it sufficiently intelligible. See plate 12. figs. 1. 2. 3. It is made conformably to an elevation on the same scale, shewing the elliptical and first segment arch from the north, sent to you in a former letter, describing the method of constructing the elliptical arch, where the cordon is described as laid down upon the key-stones, and to which I find I have not had regard in making out my design of the transverse sections, which was intended chiefly to shew the projections, by which means the whole parapet became raised six inches unnecessarily, and in consequence the thickness of the road gravel upon the top of the arches.

I am, &c.

J. SMEATON.

EXPLANATION of the Design for the North Termination of Hexham Bridge.

Plate 12. figs. 1. 2. 3.

THE line AB, shews the surface of the road to be inclined in the proportion of one in 12; and which is to meet

BC, fig. 1. The surface of the road over the first segment arch, which, if produced to the middle of the elliptical arch, will go to D.

The height of the road at B, the middle of the first pier above the springer, is as per section 17 feet, which being settled, it will pass about two feet eight inches above the sofite of the elliptical arch; that is, supposing it two feet in thickness, will allow eight inches for the gravel, and as much more as the stones in the middle of the arch are short of full two feet in the pier; and NB the exuberances, may be scappeled off, so as not to hurt the general bearings, and give their all possible thickness for the gravel at F, the termination of the abutment walls, it will pass at or about nine feet ten inches above the top of the dooming, supposed the ground level at the line E, the extreme of the road wall pillars, extending from the extreme of the abutment walls 64 feet, it will be

be four feet ten inches, that is nearly upon five feet at the center of the pillars from whence the road slopes away till it meets the natural ground, which, if perfectly level, will be at the distance of about 58 feet beyond the terminating pillars, and in this space the road is raised rampart fashion, being upheld by natural slopes on each side, like a common turnpike road.

The walking path is supposed to follow the line BD, and then keeping parallel to the top of the parapet D to G, there to descend two steps, upon the extended gravel surface between the abutment walls, where there will be room enough.

The same letters in the section, fig. 1. refer to the same parts as in the plan, and wherein the dotted lines HIKL, are supposed to be the hollowest part on each side for conducting the water, where the one in 12 slopes begins towards L, it will be proper to cross-sett this hollow with thin rubble, to prevent the sand and downfall of showers from getting a channel.

In the cross section, fig. 3. upon the line FFF, wherein

MM—Is the height of the springers.

NN—The top of the dooming or ground line.

OO—The main height of the surface of the road, being supposed a little swelled in the middle, and hollowed at the water courses, as before described.

PP—The line of the top of the abutment walls, and

QQ—The same.

Y s t o w x, is a section of the body of the termination walls, to be six feet high including caping: the inside of the caping ranges with the inside of the abutment walls, and the outside of the body of the termination walls, to be built with all the batter they can, so that the sloping face x w, does not go beyond the abutment wall of the top of the dooming.

The method of founding and building walls, and for founding the termination pillars, no part need be dug deeper than through the loose soil, perhaps one foot deep; but the

the bottom muſt be ſet with flat rubble lengthways croſs upon the foundation trench; and when done to be driven down with paviours rammers: the body of the wall to be built dry, but at every half yard in height to lay on bond ſtones well bedded in mortar, at the diſtance of two yards from each other, middle and middle; obſerving, that in the courſe of bond ſtones next above, to put them at the middle ſpaces of the courſe below, ſo that there will be in event, a bond ſtone in every ſquare yard of face; and as the bond ſtones may not be long enough to reach through the wall in one entire ſtone others muſt be laid to make good the bond quite through in mortar.

The body of the terminating walls to be built with ſomething of care, in the ſtyle of a very good field wall, the cordon to be hammer-dreſſed, and reduced to a thickneſs; the ſtone to be ſound and laid in with mortar; the parapet to be of hammer-dreſſed ſtuff of promiſcuous courſes, from three to ſix inches both inſide and out; built with mortar, and neatly walled like a farm-houſe. The caping to be of good ſound ſtone, broached and well jointed, the terminating pillars hewn where octagonal, and not hid by earth, the ſquare baſe walled and hammer-dreſſed on the ſides that will appear, the foundation rubble in mortar.

J. SMEATON.

To Mr. Pickernell.

Sir, London, 26th May 1780.

In regard to the mode of finiſhing the ſouth termination from the ſouth abutment, if the ground were as high it would be perfectly the ſame as the north; you are therefore to carry on the work ſo that all above that level ſhall be the ſame; the ſection of the walls therefore under that level will be no more than a continuance of the ſame ſection lines, obſerving to increaſe the thickneſs, not only by a continuance of the ſlope on the face, but by ſetts off on the back ſide; and as this continuance of the ſlope in part may make the foot to project conſiderably before the foundation of the main walls of the abutment, you may get rid of it by turning it a quarter round upon the abutment wall.

The declivity at top will be the ſame as the north end; and in this manner you may be going on till you come to the hollow, where I propoſe to have two arches of 18 feet ſpan, with a pillar of at leaſt ſix feet between. Theſe arches are to occupy the deepeſt part of the hollow, ſo as to vend the water with the greateſt advantage, and then to have an 18 feet arch from the ſame center over the mill leet, but ſeparated from the other two by ſuch walling as in length to ſuit the ground, and after you are over the mill leet, then to make

make a quarter turn, and terminate the walling with two termination pillars like thoſe of the north end. I propoſe to make the 18 feet arches to riſe four feet, ſo that you may be preparing the centering; and as the penſtones may be from 18 inches to one foot, as they may happen to run promiſcuouſly, you may be getting them prepared; they need no work upon them further than to bring them to a bearing. The work of the pillar and abutment walls of the arches, alſo need no other work than to make them courſe and joint; but the whole floor of the land arches I propoſe to be rough ſett with flat rubble 18 inches in height or depth, to be juſt enough ſhaped with the hammer in ſetting to make them pack like a tolerable pavement. This to be extended about 15 feet below, and about five feet above the arches, apron faſhion, and to be kept by ribbands or ſtring pieces piled down. I mean to pile under the pier and abutment walls; but as this will be particularly deſcribed by the deſign, I now mention them to give you ſome idea of the materials that will be wanted for that part of the ſervice. I don't however mean any piling or wood work but what will be got out of old ſtores.

In regard to the foundation of the terminating walls, I mean that part which you are now to proceed upon from the preceding directions, I believe the leſs you ſink below the natural ſurface the leſs you will get into ſoft matter, ſo that you may riſe and fall by ſteps according to your diſcretion; a foot into the ground, where the cover will be the leaſt, I apprehend will be quite ſufficient; this you are to croſs ſett, and drive down with a rammer, as directed for the north abutment; but if the matter on trial becomes ſoft, and in your judgement unfit to bear the weight, then you muſt drive promiſcuous piles at about the rate of one in a ſquare yard, more or leſs, as you judge neceſſary; but more rank near the front than the back ſide of the wall, and rough ſett, and driven down between the heads, ſo that the heads and ſetting may be fluſh, upon which you are to build, filling the ſpaces of the paving with quick lime and gravel, in caſe it beats to a puddle: the moſt ordinary ſtuff will do for this ſervice, that will bear driving; but get the piles down into a harder ſtratum, if you can.

I am, Sir,

J. SMEATON.

To Mr. Pickernell.

Sir, Auſthorpe, 28th October 1780.

I am ſorry that any thing ſhould have diſcompoſed any part of the outworks of the bridge, though, as it turns out by your letter, it is nothing more than might be expected, whenever

whenever a top flood came, as before that nothing was ever ſtirred, and therefore the rubble not diſpoſed as laid by the water; but as its effects ſeem to have been principally ſpent upon the fourth pier, I think it will be proper now to do with it what I have all along propoſed in my own mind, in caſe an effect ſhould take place to the degree you have deſcribed of that pier: that is, to drive ſome of the round oak piles about 18 inches diſtant, middle and middle, driving them down by ſetts three feet under the common low water ſurface: the point pile being advanced up ſtream about 15, or, if you pleaſe, 20 feet above the ſalient point of the caſing: the line of the piles to be made a little rounding, I think the upper ſide is the better figure. The internal ſpace between the piles and the caſing to be filled with rubble, as large as you can well get it, and ſome large pieces to be chocked in between the ſhoulders of the caſing and the ſhoulder piles, and then filled up with ſmaller at the top. I would alſo lay a footing ſlope of rubble upon the outſide of the piles, to be reconciled with the footing ſlope on the ſide of the caſes. As it appears from all the arches interſpaces wearing deeper, that it is the natural effect of the waters being more confined than at firſt by the interpoſition of the piers; it therefore indicates, that we ſhould not fill up more than what is abſolutely neceſſary for our ſecurity; for the more we block up the more tendency the water will have to take away the blocking and deepen the interſpaces. You have not given me the ſoundings in the reſpective interſpaces, nor told me where the rubble, &c. is chiefly lodged below the tail of the piers; if I were informed of theſe matters, as alſo whether the deepening of the interſpaces was greater at the eaſt or the weſt ſhoulders, or below the eaſt ſhoulders, I ſhould be able to tell how to direct you. You mention however that your ſoundings by the ſide of the fourth pier were eight feet; now if all lies regular, I ſhall not think eight feet too great a depth in the middle between the piers; and if the rubble ſlopes do not reach within three feet of the top of the caſings, extending above two feet in baſe to one of perpendicular height of the ſlope above the caſings, it will be as ſufficient as if higher and broader.

Nothing will ſo much tend to give an eaſy paſſage to the water through the bridge, as its ſpreading equally through all the arches. The beating jetee on the north ſide, greatly tends to prevent the water paſſing freely through the north arches, at the ſame time that it throws it upon the center one; that therefore ſhould not only be removed, but the ſhore made ſmooth and regular, the ground and all impediments removed from the north elliptical arch, and the riſing ground below it taken away; for if the water is ſtopt below an arch it is an equal impediment to the waters getting through it as if under it or above; and whatever is there ſtopped muſt be thrown upon ſome other, and the water naturally tends to find its paſſage where it finds the leaſt obſtruction;

that

that is, where the channel is the deepeſt. Our buſineſs is therefore as much as poſſible to invite the water through the ſide arches by ſmoothing and clearing all impediments to its paſſage through the ſame.

I am, &c.

J. SMEATON.

To Mr. Errington.

Sir,

In anſwer to your requeſt, deſiring my opinion in writing concerning the late calamitous accident at the Bridge of Hexham, and what is moſt adviſeable to be done upon it; I muſt, in the firſt place, obſerve to you, that from reflecting upon every circumſtance that has yet been communicated to me, with all the preciſion I am able, I am of opinion that the true cauſe of any failure was occaſioned, not only by the great violence wherewith the bridge was attacked, but by the great weakneſs of the ſtratum of matter that lies immediately under the bed of the river, and which has been ſaid univerſally to prevail in that neighbourhood by thoſe who made trial thereof, between the building of the firſt bridge and that of the ſecond; which weakneſs of the under ſtratum I was not only aware of, but turned my thoughts towards every expedient that could tend to avert the ill effects that might ariſe therefrom; and having obſerved, that in all the attempts of thoſe who had gone before me in this enterprize, they had dug conſiderably into the bed of the river, and thereby rendered that weaker which was already too weak, I did not doubt but that, by a contrary practice, my endeavours would have been crowned with the wiſhed and expected ſucceſs; for as I had read of buildings and bridges that had ſtood upon more weak natural foundations than this appeared to be, and even myſelf had a caſe of the kind, that I had effectually remedied, I did not doubt, but that with the precaution of not weakening the upper cruſt of hard gravel, but building immediately upon it, I ſhould in like manner ſucceed in this place.

The inſtances, however, that had come to my knowledge, though the ſtrata under the foundations might be naturally weaker, yet none of them are liable to be attacked with any thing near that degree of violence that this river now appears to be capable of; had it been poſſible for me to have been acquainted before hand that a flood of this river could come down with ſo much ſuddenneſs, as that, for want of time, for the lower reaches of the river to be filled from the upper, there could be created a fall or difference of level between the up ſtream end and the down ſtream ſalient point of the ſame pillar, of no leſs than five feet perpendicular, which would in effect create a

velocity

velocity of the water of above a thousand feet in a minute; I ſay, could I have been informed of this ſingle fact, as appeared to be at, and for ſome time before any degree of derangement was apparent in this bridge, I never could have thought of adviſing you, or any private gentleman, to have undertaken, at his own riſk, a building of ſo much danger and hazard; and, excluſively of that danger and derangement which might naturally be expected to ariſe from the mere rapidity of the water, I am further of opinion from what now appears, that the mere difference of the weight of the body of water immediately above the bridge, which could not be counterbalanced by a body of water of an equal breadth immediately below, has, in reality, been ſufficient to force down the under ſoft ſtratum out of its former poſition, ſo as to be more inclined to the weſt, and occaſioned the upper ſtratum, upon which the bridge immediately ſtood, to follow it; and in both theſe reſpects, that is, of rapidity and unequal preſſure upon the bottom, the violence would be greater than even in the great inundation of 1771; for though, acccording to accounts, the height of that was greater, yet its riſe was far leſs ſudden; and therefore its rapidity and tendency to derangement leſs.

To the queſtion, What is now to be done? I anſwer, that though I do not conceive it impoſſible to re-erect the bridge in the former ſite, and where much expenſe is ſtanding towards a completion; yet I do conceive it impoſſible to be done with any reaſonable hope of its proving a permanent or ſucceſsful undertaking. I am further fully convinced the bridge was perfectly ſafe againſt all common occurrences.

I remain, Sir,

Your moſt humble ſervant,

J. SMEATON.

Gray's Inn,
6th April 1782.

P. S. The bridge I mentioned to have reſtored was the Bridge of Dumbarton, about 20 miles from Glaſgow, undertaken by government. That part of it that failed was built upon a cruſt of gravel not above two feet thick; and, without any flood, external violence, or previous notice, one of the pillars went down, with the two adjacent arches, and cruſhed the centers, then ſtanding, under them. On examining, I found the ground ſo ſoft under this cruſt of gravel, that a bar of 40 feet went down to the head by its own weight.

To

To Mr. Pickernell.

Dear Sir, Auſthorpe, 6th June 1782.

All our honours are now in the duſt! It cannot now be ſaid, that in the courſe of thirty years practice, and engaged in ſome of the moſt difficult enterprizes, not one of Smeaton's works has failed: Hexham Bridge is a melancholy witneſs to the contrary; yet, after all, I feel much leſs for honour and credit than I do for the actual loſs ſuſtained by Mr. Errington: it would give me much ſatiſfaction if that matter were ſettled between him and the county. I have heard that his appearance there at the Eaſter ſeſſions much inclined the magiſtrates to ſee the matter in a favourable light; but the difficulty was, how far it was in their power.

I ſaw Mr. Donkin in town, who acquainted me, that he was looking at it when it firſt appeared to give way; his ſon being but juſt returned from the ſouth ſide, to ſee that the ſmall arches there were ſafe, which was the only part that they had any doubt about. He was wondering at the poſſibility that any ſtructure could withſtand ſuch extreme violence, yet not at all expecting that any thing would hurt it; and remarked that before any thing appeared to give way, the water was up to the top of the dooming of the piers up ſtream when it ſcarcely touched the bottom of the impoſt down ſtream, which makes a fall of five feet, and it was not above a couple of minutes between firſt perceiving the mortar dropping out of the joints of the ſofit and the fall of the arch, and ſix more were down in half an hour, ſo that it was ſo equally guarded that in a manner it all went together. Could I have known beforehand that there was a poſſibility of a flood to come down ſo *ſuddenly* as to have made a fall through all thoſe extenſive openings of five feet, I ſhould certainly never have attempted the building a bridge in that ſituation, as that fall would neceſſarily create a velocity to the water in its paſſage of 1100 feet per minute: a velocity that it would require the ſtrongeſt ſluice-floor and aprons to withſtand. I am therefore clear that it has forced away the very bed of the river and all before it. The occaſion of this extreme ſuddenneſs in the waters coming down, which in that reſpect was far greater, according to all accounts, than in the great inundation of 1771, though the total height not ſo great, was, doubtleſs, owing to this circumſtance, that the afternoon before a very great downfall of ſnow happened, ſo deep as to cover the ground at an average two feet. This was immediately ſucceeded by a vaſt downfall of rain, none of which would run off, till the whole body of ſnow was ſaturated like a ſpunge, and then, like the burſting of a ſnow-ball in the fire, it would come down all at once, and that ſo ſuddenly, that the lower reaches of the river not having *time* to be filled from the upper they would be comparatively empty; and as the velocity of water depends upon its fall, or *difference* of level at any given place, and not upon its total height, the difference will depend

depend upon the ſuddenneſs of its coming down; and this being further hurried down by a violent gale of wind at north-weſt, the very direction that, upon the whole, would tend to bring it down the quickeſt from both the Tynes, it would ſeem as if all the powers of nature were collected to humble my pride and yours. The news came to me like a thunderbolt; as it was a ſtroke I leaſt expected, and even yet can ſcarcely form a practical belief of its reality. A flood that could mount up to the top of the doomings of the piers was, however, not a ſmall, or even middling flood, in point of height; and as every object that entangled it would moderate its rapidity, it is not improbable but that the downfall of Hexham Bridge might be the ſaving of Corbridge; and by the ſpreading gradually over the wide haughs in many places below, was not more than a moderately large flood at Newcaſtle. There is, however, one conſolation that attends this great misfortune, and that is, that I cannot ſee that any body is really to blame, or that any body is blamed: we all did our beſt, according to what appeared; and all the experience I have gained is, not to attempt a bridge upon a gravel bottom in a river ſubject to ſuch violent rapidity.

I remain, your moſt humble ſervant,

J. SMEATON.

P. S. I cannot ſuppoſe any failure ariſing from the greenneſs of the work, but wholly from the whole bed of the river giving way under it; as nothing appeared to ſettle till it gave way in a manner at once, which is a proof of its being firmly bonded together.

A COPY of Mr. Mylne's Opinion and Report, delivered to the Magiſtrates of Northumberland, reſpecting the Practicability of building a permanent Bridge at Hexham, on the Site of that built by H. Errington, Eſq.

Hexham, April 24th 1783.

To the Magiſtrates and Juſtices of the Peace in and for the County of Northumberland, in General Meeting aſſembled.

Gentlemen,

BEING requeſted by you to view and examine the preſent ſtate of the Bridge acroſs the river Tyne, lately built by, and at the expenſe of Henry Errington, Eſq., agreeably to the plan and advice of Mr. Smeaton, and to inſpect the ſite and nature of the bed of the river, whereon the ſame was conſtructed, I beg leave to report, that it fully appears, this bridge was undermined by the great flood, which happened on the eleventh day of March 1782, and that the ſoil and ſubſtance of the bed of the river, of whatever matter and quality the ſame conſiſted, was dug or ſcooped out from below the greateſt part of the piers, and *that* towards the weſt or upper ſide of the bridge,—and the advanced or guard works, incloſing a ſpace round the piers, for the better ſecurity and maintenance of the ſoil immediately under the piers, whereon the whole weight of the ſtructure had been charged, were alſo undermined by the gravel and ſand, into which they had been driven, being worn away by the velocity of the ſtream; thus circumſtanced during the height and greateſt rage of a flood, it will appear no wonder that the piers, having a fourth, half, and even to three-fourths of their baſe taken out from below them, the arches ſplit in two longways, by ſome of the piers breaking acroſs, into two parts, precipitated into ruin themſelves, and the parts conſtructed upon them.

All the piers fell towards the ſtream, but took different inclinations towards the excavation of the bottom, ſometimes made more on one ſhoulder han on the other of each pier.

The ſurface of the water-line is now twenty-two inches lower than in the time during which the bridge was conſtructed; I have bored the river at the bridge to the depth of twenty-three feet below the latter water level, in a place where I might not be led aſtray by any alteration formed by the ſaid flood, in the height of its impetuoſity; and ſkimmed over again in its milder velocity; and I have found under the teſtimony and perſeverance of Mr. Wake, that the ſoil and texture of the bed of the river at this place, is uniformly a compoſition or congeries of roundiſh and flat ſtones, gravel and ſand, of equal quality and conſiſtence in the whole of that depth.

The piers which were founded by means of a batter d'eaux, have ſtood tolerably well, and thoſe which were laid by caiſſons, having no piles directly under the piers, were the eaſieſt prey to the vaſt powers of this flood.

The depth to which all the works in general, whether immediate or preſervative, were carried was far too ſhallow, and too little into the bed of the river, which (though hard to the touch of boring and compact to the eye, and feeling of inſtruments) is wonderfully looſe, and unconnected in its parts, in ſo much, that the bed of the river Tyne ſeems to ſhift and alter its form, extent and ſituation, with every flood more or leſs, and tearing up at one time to a great depth, that fair moulded and well laid hollow, which the ſtream had laid for itſelf on ſome former occaſion.

In

In ſuch a ſituation, under theſe circumſtances, with the additional one of many piers being to be fixed as obſtacles to its violence, the foundations could not be laid too low. To what depth they ought to have been laid, and the means to be deviſed for that purpoſe, lay and remain with the parties engaged in the performance.

Mr. Smeaton, than whom there is no perſon or artiſt better inſtructed, more knowing, and of a more penetrating and correct judgment, muſt have been deceived in the collection of facts and materials, on which he eſtabliſhed his plan of operations.

A great mind is often deceived by its own virtues. Habituated to give, on all occaſions, the genuine and honeſt productions of its faculties, it often relies too much, and implicitly, on that which appears to be the ſame of other perſons.

The exiſtence of a ſand below, and a ſuppoſed hardneſs and concretion of five feet or any ſuch meaſure of the upper parts, ſeem to have precipitately and fatally determined the plan of operations, at firſt ſetting off, and appear to me to be equally the cauſe of the preſent precipitate opinion, for abandoning the propoſition as impracticable.

Art furniſhes the means, I humbly preſume, of going to a ſufficient depth, with all the foundations, and that too, on the ſpot, notwithſtanding the damage which this ſite has received.

To compare the eligibility of this ſituation with that of any other near to Hexham, and the direction of the Alemouth road, is perhaps uſeleſs to diſcuſs at preſent.—But in my opinion, if nothing had hitherto been done, (as too much has unfortunately been done) I would have recommended a place of deep water, and fixed elevated banks, like to that oppoſite to the weſt end of the dwarf wall of the Spital Green within Mr. Waſtell's incloſures.

To enable me to form the opinions, which I have now the honour to report to you, I have ſeen and examined all Mr. Smeaton's papers, I have heard all the particulars, and hiſtory of his proceedings, and motives for the method of operations which he adopted, I have examined every part of the works, and many perſons concerned, and employed in the detail of its execution; and it was my lot to paſs here in Auguſt 1778, when I viewed the effects then produced, in thoſe very foundations, by floods previous to that time, making for my own inſtruction, minutes of what then I ſaw.—I mention theſe things to enable you to judge of that reliance, you and all other parties intereſted in this buſineſs, may be pleaſed to give to theſe opinions, and to this report, which is made by

Your moſt obedient, and very humble ſervant,

ROBERT MYLNE.

Mr. SMEATON'S Memorial concerning Hexham Bridge.

WHEN Mr. Smeaton was applied to by Mr. Errington, for the building of Hexham Bridge, it was not till after the total deſtruction of a bridge at the weſt end of Tyne Green, near that place, built under the patronage of Sir Walter Blackett; which, about twelve or fourteen months after it was finiſhed, was totally deſtroyed by an extraordinary flood, that has ever ſince been diſtinguiſhed by the name of the Great Inundation, which happened in November 1771; but as this bridge was ſtanding at dark in the evening, and totally demoliſhed the next morning, no other information could be drawn from this very fatal and alarming accident, but that this river was capable at times, from a certain combination of cauſes, of being ſwelled to a degree of violence far exceeding any thing that had before this been experienced, handed down by tradition, or imagined.

As an evidence of this, amongſt many others that might be given, the water roſe ſeven or eight feet, or thereabout, upon the main ground floor of Mr. Fenwick's new-built apartments at Bywell; which being erected from the deſigns of that eminent architect Mr. Payne, it is not likely that he would direct the main floor to be laid within flood-mark, as it had, at that time, been known, or then thought likely to happen; and yet, Bywell being many miles below the junction of the two Tynes (that is of the North and South Tyne, about a mile above Hexham) and after it had had much room to ſpread over the wide haughs that laid between Hexham and Corbridge, and alſo in the ſpace between Corbridge and Bywell, we muſt conclude, that the riſe of the water was leſs at Bywell than in the neighbourhood of Hexham.

Under this degree of information, and experience of the utility of a bridge at Hexham, (Sir Walter Blackett having choſen rather to forfeit the penalty of a bond of three thouſand pounds, that he had laid himſelf under for the upholding thereof, than attempt to rebuild or re-eſtabliſh the bridge), the erection was taken up by the county; and, for this purpoſe, conſulted that eminent engineer Mr. Wooler, then engaged for the town of Newcaſtle, in the re-eſtabliſhment of Tyne Bridge there, ſo far as the magiſtrates of that town were concerned therewith, and (which through the Fan down the river, and in the tides-way, ſuffered alſo an almoſt total demolition) Mr. Wooler, on faith of borings made by a ſurveyor, a perſon employed by the magiſtrates of the county for that purpoſe, who reported, that a bed of clay laid at no more than four feet under the bed of the river, at a place about fifty yards above, or weſtward of the bridge built by Sir Walter Blackett, formed a proper deſign

defign for building a bridge upon the foundation defcribed, upon the principles of piling and planking under the piers, and which was begun accordingly in the year 1774; and, after building the north land-breaft, Mr. Pickernell was recommended in the beginning of the year 1775 to the county, by Mr. Wooler, and employed as furveyor under him for the erection of this bridge; who having funk the foundation pit for the firft pier from the north abutment, as directed, to the depth of four feet below the bed of the river, to find the bed of clay; inftead thereof, came to a ftratum of a very different nature, which, after examining, he reported to Mr. Wooler, then at Hull, viz. " A quickfand full of " bubbly fprings, and of fo loofe a texture, that by hand only, a bar of iron entered " into it forty-fix feet without meeting any refiftance; and that a trial pile of whole timber " entered twenty-fix feet, at two inches and a half per ftroke of the ram without floping; " and that the gentlemen concerned were eye-witneffes to the facts."

Upon the above report Mr. Wooler declared his opinion, that the attempting to fet a bridge upon fuch an enormous depth of quickfand, over a river fo fubject to great floods as the Tyne, may be deemed fo hazardous, as to be next to imprudence itfelf — and again, that this wretched quickfand, rendered the attempting a bridge on fuch principles (that is piling and planking under the piers) little better than folly — a quickfand, which, from its refiftance to the iron bar, cannot be deemed much better than a heap of chaff. For, fays he, " let it again be fuppofed, that a flood like that which overturned the late bridge " fhould happen, it cannot be doubted, that when the loofe gravel under the bed of " the river (only four feet thick) fhall be fwept away between any of the piers, the " quickfand under it will prefently follow like water itfelf; and an excavation may be " made in a few hours, as deep or deeper than any of the piles that guard the piers; " when a downfall muft be the immediate confequence. On thefe principles therefore, " the bridge ought not to be attempted in this fpot; and, if no better can be found in " any other fituation, there is but one method of dealing with fuch ground, which has " fucceeded where expenfe was not regarded: that is, by carrying a folid wall quite " through the river, from fide to fide, about fix feet high; and in this cafe it muft be " forty-two feet broad." The preceding extracts are made from a copy of Mr. Wooler's letter of the 19th of July, 1775, to Mr. Pickernell; the perufal of which will more amply fet forth the grounds and reafons of Mr. Wooler's opinion; that no bridge under fuch circumftance, is likely to be accomplifhed at any limited expenfe; he concludes with faying, " I had the honour to mention this method (that is of the folid wall) " to Mr. Aynfley, when there was a doubt about the nature of the ground, fometime " before their furveyor found out the ftratum of the clay; but he then looked upon the " expenfe to exceed their abilities; but however, after all, if ever a ftable bridge be " made there, I do not know any other means to effect it — You will lay this before the " gentlemen for their confideration."

After this, Mr. Pickernell proceeded to fink a well or fhaft in the folid foil of Tyne Green, near the place where the fouth abutment of the intended bridge was to be; when paffing through the ftratum of gravel, found the quickfand at nearly the fame depth, (that is to fay, four feet below the bed of the river) as in the foundation pit for the pier on the other fide, into which he thruft his iron bar as before, and covered up the fhaft, till Mr. Wooler fhould come and examine the premifes.

He alfo proceeded to try the river, by boring in other places; and particularly in the pool below the eaft boat; that is, a little above the place where Mr. Smeaton afterwards pitched upon, to build a bridge for Mr. Errington; an account of which boaring being tranfmitted by Mr. Pickernell to the clerk of the peace, reference being thereto had, will more fully appear; but which went to prove, that whenever Mr. Pickernell had penetrated the bed of gravel, univerfally a ftratum of quickfand was found.

Under thefe circumftances Mr. Wooler attended at Hexham, to furvey the premifes; and in the prefence of fome of the magiftrates affembled on the occafion, repeated the trial of the bar, both in the foundation pit near the north, and in the fhaft near the fouth-end of the intended bridge, and which fucceeded as before mentioned. The exiftence of a ftratum of quickfand under a bed of gravel in this place, then, does not depend upon the fimple teftimony of Mr. Pickernell, but is alike witneffed by very refpectable, as well as competent judges.

The refult of which view and furvey was, that no other place appearing more eligible and likely, than where the beginning had been made, and being unwilling to go on upon the principle intended and began, of piling and planking under the piers; and the magiftrates not giving ear to the folid wall propofed by Mr. Wooler (acrofs and under the whole bed of the river, from fide to fide, as an artificial foundation whereon a bridge was to be erected), on account of the expenfe thereof, which was not likely to be uncertain, but fo great as to be very imprudent for even the county to enter upon, the whole undertaking was at that time given up or fufpended: and Mr. Wooler having been urged, as too eafily defifting from his original plan, on going away, he very fagacioufly and prophetically faid, whoever meddled with a bridge there, would burn their fingers. After this the gentlemen of the county, unwilling to lofe fight of a bridge at Hexham, an advertifement foon after appeared in all the Newcaftle newfpapers, as from the bench of magiftrates of the county

county, importing an invitation to all adventurers to undertake the erection of a bridge, taking the risque of making a foundation upon themselves, and taking their own method of doing it, but to build the superstructure according to a certain design to be produced to them, and security for the permanency of the whole for the term of seven years. This advertisement was continued till the latter end of the year 1776, in which interval several adventurers had in succession offered, but all of them on a closer view, before the completion of a contract, started off; several expensive preparations having been made at the expense of the county, and the materials lying upon their hands: this work being therefore, as will appear from what is preceding, generally considered as a derelict scheme, or at least a forlorn hope; some time in the latter end of the year 1776, Mr. Donkin, agent of Mr. Errington, came to Mr. Smeaton in Mr. Errington's name, to know if he would undertake the direction of building a bridge over the Tyne, somewhere between the Lowford, and the Eastboat at Hexham, for Mr. Errington, provided he (Mr. Smeaton) could find a place for the founding thereof which he thought so sufficient, as that he would risque his credit upon it as an artist: in which case, if it could be done upon a moderate estimate, he (Mr. Errington) would make a proposal for building it to the county; urging, that as the county had been so long baffled in the attempt, as it would be an advantage to his estate, if it could be done there, it was probable that if it could be done at a moderate expense, the county might accept of a bridge there, rather than none, and if he (Mr. Errington) was two or three hundred pounds out of pocket on the above account, he would think it worth his while.

Mr. Smeaton, being somewhat surprized at the uncommonness and newness of the proposal, desired time to consider of it, as previously to that time, he had studiously avoided having any thing to do with it; though he had been frequently in that neighbourhood for a course of years, comprehending, and even preceding, the time of first undertaking thereof by Sir Walter Blackett; but considering it on this occasion as a great advantage to the public, that if that could be done which they then seemed unlikely to get done; he began to consider the causes of failure in those that preceded, and in thinking seriously of the subject, there occurred to him a mode of construction, that could not only be executed for a very moderate expense, considering the extent of the subject; but the only mode in which a bridge could be executed, on such a kind of foundation as was then generally supposed, at any moderate expense and with a reasonable prospect of safety.

This considered, Mr. Smeaton acquainted Mr. Donkin, that he was willing to examine the situation; and if he found it competent, so that he could hazard his credit as an artist

upon it, he would be willing to give Mr. Errington an estimate. The trial was made, assisted by Mr. Pickernell, who on this occasion recounted the principal part of what is above stated, so far as he was concerned; the estimate was made, presented and accepted, the bridge undertaken, built, and suffered the fatal overthrow that has occasioned the present litigation.

The preceding narrative will sufficiently show, that none of the parties pressed themselves into this unfortunate, this ill-fated business, or proceeded in it from any interested motives.

Respecting Mr. Errington, he neither professed nor could ever have any view of profit from the undertaking, the contingent benefit that it might in that situation be to his estate, being the sole motive of the pains and trouble that must necessarily attend it.

Respecting Mr. Smeaton, he neither asked, expected, sought, nor received more than his accustomed daily hire, and he trusts, that it will not be supposed, that he could wish to undertake this business for want of employ; and in respect of Mr. Pickernell, if he wanted employ, he would have been much more likely to have met with it, by the bridge being proceeded with, if he had reported a good gravel to an unfathomable depth, knowing or believing there was a quicksand at nine or ten feet under it, than he could expect from reporting a quicksand, at nine or ten feet under the surface of the gravel, knowing or believing it was gravel unfathomable; because being then not at all acquainted with Mr. Smeaton's ideas of the proper method of treating such a subject, he must suppose it more likely for a bridge to be undertaken and proceeded with, if the foundation was a gravel unfathomable, than if it was a gravel with a quicksand under it.

What remain, therefore, as questions material to the county and to all the parties, seem to be the following, and what they who undertake to judge of the whole matter, should be acquainted with.

1st, Whether Mr. Smeaton from the whole matter before him, at the time of forming his project, did it with that deliberate judgment and reasonable probability of success, that have characterized him in other things?

2dly, Whether Mr. Errington was ſparing of any thing neceſſary to give ſucceſs to that mode of building which Mr. Smeaton had adopted?

3dly, Whether Mr. Pickernell did to the beſt of his power and abilities execute, to a reaſonable and poſſible extent, what he was directed by Mr. Smeaton?

4thly, Whether under all the experience and knowledge of the ſubject, as it now ſtands, the preſent bridge ſhould be attempted to be re-inſtated, or a new one built at Hexham?

With reſpect to Mr. Smeaton's ſcheme for the bridge, the following matters are worthy of obſervation:

1ſt, That from the failure of Sir Walter's bridge in the night, no eſtimate could be formed, of the fall or velocity that the water had in paſſing that bridge, at the extreme of the flood, before its failure: for though the marks of the flood were left very viſible, which ſhewed it to have riſen many feet higher than any former flood, in point of height; yet this gives no light into the ſtreſs laid upon the bridge by the velocity of the water, for no bridge, even tolerably built, ought to ſuffer from the water's riſing any height upon it whatever, if ſtagnant or riſing very ſlowly, by the counteracting of a riſing tide oppoſing the natural current.

2dly, That it is aſcertained beyond a doubt, that at the place where Mr. Wooler began, there in reality exiſted a quickſand of an unfathomable depth, covered with a bed of gravel, of a very moderate thickneſs and conſiſtence, and intermixed with large tumbling white ſtones.

3dly, That not only from the faith of Mr. Pickernell's ſubſequent borings, but from the proximity of the two ſituations (not one-third of the breadth of the river aſunder), it appeared in the higheſt degree probable, that the ſame, or ſome ſuch a ſtratum of looſe matter, lay under the foundation of the bridge built by Sir Walter Blackett, and was the cauſe of its deſtruction; otherwiſe, its ſudden and total deſtruction, in ſo ſhort a ſpace of time, was to Mr. Smeaton totally unaccountable; who in the way of curioſity (as other buſineſs often carried him to Hexham) had ſometimes viewed the operations of that bridge while it was building: that bridge having been in his judgment at that time competently well founded to guard againſt accidents, conſidering in what manner it

it was done, when compared with the manner of founding on gravel uſed by our forefathers; and which, for Sir Walter Blackett, was deſigned and undertaken at the riſque of that ingenious and well experienced builder Mr. John Gott, of Woodhall, in the Weſt-Riding of the County of York, who for ſeveral years previous to that, had been undertaker of the building and repairs of the county bridges in the ſaid Weſt-Riding, and alſo ſurveyor of the rebuilding and repairs of the navigation works upon the rivers Aire and Calder; a man rendered truly reſpectable to all who knew him, from a long ſeries of ſucceſsful experience in this kind of arduous undertakings; and who, moreover, previouſly to this undertaking at Hexham, had with great ſucceſs and credit to himſelf, then undertaken and completed the new bridge at Ferrybridge, in Yorkſhire, which was done upon the ſelf ſame principles that he afterwards put in practice upon the Tyne, and which bridge ſtill ſtands unhurt upon the river Aire (there alſo united with the large river Calder) to the praiſe of the ſkill of the worthy builder thereof.

This perſon, Mr. Gott, being perſonally known to Sir Walter Blackett, as well as his works, Sir Walter pitched upon him as a proper perſon to enſure ſucceſs to his favourite project; and ſtill the more effectually to do it, he joined with Mr. Gott, Mr. Brown, a very worthy and experienced maſon of the neighbourhood; a perſon that had acquitted himſelf by many works done for Sir Walter and others, and ſome in the bridge way, and was alſo at that time ſurveyor for the bridges of the county of Northumberland: and ſtill the further to ſecure their care and induſtry in this undertaking, he had them bound to him as undertakers for the ſum for which they contracted with him, to uphold their works for the term in which he ſtood engaged to the county; but as a demonſtration, that ſhews how well he was ſatisfied, that the care and ſkill of the undertakers were fully and properly exerted, he, after the accident and a full examination, gave them up the bond they had entered into with him, contenting himſelf to pay the penalty in which he ſtood engaged to the county.

And now, as it will throw a conſiderable light upon what I have to ſay further upon the ſubject, it will not be loſt time to explain the mode of founding, adopted and put in practice by Mr. Gott, as it appeared to Mr. Smeaton by ocular inſpection, and who at the time was acquainted with the undertakers, but more particularly and previouſly with Mr. Gott.

Having

Having conſtructed large and broad coffer dams of earth to fence off the water, by the help of chain pumps, they ſank the foundation pit about three feet into the gravel, then they drove piles over the whole area of the intended foundation of each pillar, from ten to twelve feet long, and from ten to twelve inches diameter in the heads, and tapering according to the natural taper of the timber, proper for driving into gravel of conſiderable reſiſtance. The heads being cut to a level, the whole was covered by a platform, made of whole (that is twelve inches) Riga balks, rabbetted or halved into each other, ſo that each could not ſubſide without its neighbour going with it, and upon this platform the pillars were reſpectively built.

Mr. Smeaton has reaſon to believe (though he never happened to be there when any piles were driving), that the undertakers finding their piles go into the ground more eaſily than they expected, and the upper part the hardeſt, did not in all the pillars make the excavation of the foundation pit quite ſo deep as above mentioned, but yet all were founded below the bed of the river: and, in a converſation with Sir Walter Blackett, after the founding the bridge was done, Sir Walter obſerving to Mr. Smeaton, that a rumour had gone forth, that the founding of the bridge had not been made ſufficiently ſtrong, Mr. Smeaton ſaid, that had they encreaſed the circumference with plank or ſheet piling, as he had done in all the gravel foundations of the kind, that he had had the ordering of, it was all he ſhould have done more than was done; but as the laying a ſolid platform, and even the piling itſelf, were things that our forefathers had not generally practiſed in ſuch caſes, and yet we found many of their bridges ſtanding after many years trial; it muſt be ſomething very extraordinary that could hurt a foundation ſo laid, far beyond any thing wherewith we were then acquainted.

This ſerves to ſhew what the opinion of Mr. Smeaton was at that time, before any derangement had happened, ſo that it was a matter to him of very great ſurprize, that notwithſtanding the extraordinary height of the water, a bridge ſo founded ſhould be ſo entirely demoliſhed in ſo ſmall a ſpace of time; but when the operations of Mr. Wooler were known, his ſurprize ceaſed: looking upon it as a certainty, that the violence of the water having taken off the cruſt of gravel, wounded alſo by the excavation for the piers, ſo as to let looſe the quickſand, he no longer wondered at the ſudden demolition of the bridge.

The third matter to be obſerved is, that Mr. Smeaton had at that time, (that is, at Mr. Donkin's application) finiſhed with ſucceſs two capital bridges in Scotland, over

two of the reputed moſt rapid rivers of their magnitude in that part of Great Britain; that is, over the Tweed at Coldſtream, which was finiſhed about the year 1767, and the Tay at Perth, which was finiſhed in or about the year 1770, and which in the interim before Mr. Donkin's application, had ſuſtained many ſevere attacks from floods, but without any injury, except (in ſome ſlight degree) to the rough rubble ſtone depoſited round the piers by way of defence, and which being occaſionally replaced, the whole remained and does ſtill remain unhurt.

Theſe bridges, the firſt being in part, and the latter wholly upon gravel of unfathomable depth, were founded on bearing piles, encaſed with ſheet or plank piles, below the bed of the river, the ſpace being filled up, and the foundation farther defended by the depoſition of rough quarry rubble ſtones: and Mr. Smeaton having experienced the great dependence and power of reſiſtance of ſtones ſo depoſited, not only in the caſes of building the bridges above mentioned, but in a great variety of caſes, preceding thoſe undertakings as well as after, wherein he found them the moſt effectual means, not only of controuling the violence of rapid rivers, but of the ſea itſelf, he was naturally led to place very great confidence in that ſpecies of defence.

4thly, That partly from the report of Mr. Pickernell's borings, partly from the ſimilarity of ſituation of the place propoſed by Mr. Errington, to that where Sir Walter Blackett and Mr. Wooler had worked, being both of them near the bottom of an extenſive pool, wherein the water is kept up by a bed of gravel juſt below them, and forming as it were a natural dam, whereby the motion of the water in the pool above, in the low ſtate of the river, was ſcarcely perceptible; I ſay, from ſimilarity of ſituations, Mr. Pickernell's report of the ground, juſt above the place pitched upon by Mr. Smeaton, and the trials that he (Mr. Smeaton) made himſelf, by driving a ſharpened iron bar from nine to ten feet into the bed of the river in ſeveral places, which was very conſiderably leſs reſiſted, and particularly in the main current, after it was driven down ſome feet, than it was in entering the upper cruſt of the gravel bed, which was apparent to him, by his aſſiſting perſonally in the operation; from all theſe conſiderations he thought himſelf well juſtified in concluding, that at ſome depth, exceeding nine or ten feet, at this place, there either actually exiſted a ſtratum of quickſand, ſimilar to that at the weſt end of Tyne Green, or at leaſt matter ſo little compact or capable of bearing weight, that to drive piles into it would only weaken the ſtratum. The queſtion therefore, that he had to decide for his own guidance was, Whether there was a bed of gravel of ſufficient thickneſs and compactneſs to bear the weight of a bridge, in caſe it was unwounded and unbroken? And the experiment of the bar abovementioned

(which was tried in feveral places acrofs the river), determined his judgment, that what he had felt and experienced was fufficient.

It may here naturally be enquired, why Mr. Smeaton did not bore the bed of the river, inftead of driving the bar in the manner defcribed? and he anfwers, becaufe former experience had taught him to have very little faith in boring in gravel, for the purpofe of founding bridges; for the colliery borers, though exceedingly expert in boring for the purpofes to which they are to apply them, yet are no competent judges of the compactnefs of the ftratum for the purpofe of building a bridge; and in the trials formerly made by Mr. Smeaton himfelf, from the continual falling in of the fmaller parts of the gravel itfelf, while the flank of the inftrument is turning round, thereby occafioning a continual grinding; and if the inftrument is attempted to be withdrawn, the holes immediately filling, made it never appear to him in the light of a fatisfactory operation, convincing to his mind of any certain conclufion: he has therefore, for many years paft, contented himfelf with trials by the bar, which being driven by a hammer, he judges of the compactnefs of the gravel, by the number and ftrength of the blows that it takes to go down; and on the faith of trials of this kind, where the bar went down with a competent refiftance and a near equality, he built the bridge of Perth upon piles encafed with fheeting.

From a mature confideration of the above particulars and circumftances, Mr. Smeaton found himfelf led to the following conclufions, viz.

That to build a folid wall acrofs the river as a foundation for the whole bridge, in the manner propofed by Mr. Wooler, would not only be attended with an enormous expenfe, but, in the place where he propofed it, likely to be in itfelf impracticable: for it did not, nor does it occur to Mr. Smeaton, how this is to be done without draining off the water from the bottom of the very large excavation that would be neceffary to be laid open at once; which muft not only go down to the quickfand, but in reality confiderably into it, to lay the propofed foundation of the wall; that in cafe the quickfands fhould break up and run, as it was moft likely to do, the drainage of this liquid matter would be endlefs; and if any part of it was attended with fo much fuccefs as to get founded, yet the part fo founded would be fapped, when the fand is fo broken up in any fucceeding part.

That though in the place pitched upon by Mr. Smeaton, the bed of gravel appeared both thicker and firmer than where Mr. Wooler had begun; yet, as it appears evidently to him, was likely to partake of the fame quality, the execution of the fcheme of the folid wall, or of penning as propofed by others (to make which effectual muft amount to the fame thing) could not be done upon any limited eftimate; and at any rate, would exceed all bounds of expenfe, that it appeared to him likely or indeed prudent to be gone into by the county.

That to attempt the building of the bridge upon the principles of that of Perth; that is, to fink an excavation pit confiderably into the bed of the river, and in this to pile and encafe, would be, in effect, firft to deftroy the very beft and firmeft part of the ftratum, and then by driving piles into what was likely to be incapable of bearing the weight, would be in reality to repeat the errors, that, as it feemed to him, had been committed in Mr. Gott's erection; and as, laft of all, the fecurity of the bridge in any of thefe methods, muft ultimately depend upon the defences to be made by the judicious and proper depofition of rough quarry rubble; it appeared to him a folly, firft to deftroy the firm upper cruft of gravel that he reported verbally on his trial thereof to be comparatively hard, like the pavement of Hexham ftreets, and then, at a great expenfe, fubftitute fomething not fo much to be depended on, and this ftill want defending by quarry rubble, which in every cafe could be applied: and he muft here beg leave to remark, that a quarry, fituated moft commodioufly to this fituation of the bridge in the eftate of Mr. Errington, offered the greateft plenty of this kind of material, and of the moft excellent quality for the purpofe that he has any where had the experience of.

From the whole of the premifes he concluded, that the fafeft way would be to preferve the upper cruft of the bed of gravel inviolably unbroken even by a pile; and particularly in the main channel of the river, where the diminution of the hardnefs of the upper cruft principally to him appeared; fo that, concluding to build the two land-breafts upon piles, with cafting, and alfo the two pillars next thereto, in the fame method, with coffer dams to drain out the water (he having found that within that compafs the bed of gravel appeared equally hard and compact) the method that naturally offered itfelf was to found the reft of the piers by caiffon; a method the moft eafy and ready, and attended with the leaft coft of any. So that having before abundantly experienced that good quarry rubble would refift the action of a current to a greater degree than any kind of gravel, it appeared that the pillars fo funk, being defended from accidental flood till they could be furrounded by a flope of rubble (which the depth of the water naturally admitted in this place) hence would arife every degree of fecurity that the nature of the fubject would admit of.

He

He concluded therefore to build a bridge of nine arches inftead of feven, that it might have more legs to ftand upon, in confequence of the natural weaknefs of the ftratum; and by way of fecurity to the piers, before they could be properly and fufficiently furrounded by the propofed flope of rubble, as well as after, in cafe of any derangement to the rubble defence, a girdle of ftones in blocks of a ton weight and upwards, was propofed to be let down, and furround the bafe of each pier, to be fitted to each other, and to the pier they furrounded, and to be cramped together.

Upon this idea of conftruction Mr. Smeaton formed his original eftimate; and which, from the fimple mode of it, could be executed for a very moderate fum of money, in proportion to the largenefs of the river and extent of the work; and which, in confequence, was bargained for by Mr. Errington, and the work proceeded with accordingly.

The north land-breaft and the adjoining pier were fuccefsfully built upon piles encafed as propofed; and the gravel being there very fufficiently compact (fo as to afford only a moderate quantity of water) Mr. Smeaton determined to try to go on as far as he could upon that principle, and therefore ordered the fecond pier from the north abutment to be tried with a coffer dam, to encavate and found like the firft; but when the pit was funk but two feet under the level of the water outfide, and not much more than half as much under the natural bed of the river, the water boiled up between the interftices of the gravel ftones, bringing fand along with it, that it required forty men continually at the pumps to keep it down; and it was not without the utmoft difficulty that the pier was founded on that principle at that depth.

The fouth abutment and contiguous pillar were alfo fuccefsfully founded, according to the original intentions; but at the fecond pier from the fouth, the water being much deeper (being in the main channel, and the gravel bottom clean wafhed, like the fecond from the north) Mr. Smeaton judged it in vain to attempt any more pillars by coffer dams, becaufe it would be an ufelefs expenfe to conftruct a coffer dam without the leaft probability of maftering the water.

Early in the fummer of 1778, the remaining five pillars were begun to be executed by caiffons, and Mr. Smeaton attended the execution of the firft that was laid, which was the fourth pier from the north fide of the center arch; and which was done with fo much expedition, eafe, and convenience, that the feafon and weather turning out remarkable fine, the whole body of agents and workmen preffed forward to get as many of

of them done as poffible while that favourable feafon lafted; but a number of blocks for the girdle courfe not immediately arifing out of the quarries of a fufficient fize for the purpofe, about the latter end of July four out of the five caiffon piers were grounded upon the bottom of the river, and brought above water, when only one of them had any of the girdle ftones brought and depofited, and this only in part around it; beginning from the weftern or up ftream falient point, and extending from thence about half way round the pier on each fide: in this ftate of things, after a remarkably dry feafon of fome months, there came a violent rapid flood, not indeed a very high one, but the river being previoufly empty of water, and the rain which occafioned it falling very fuddenly, it came down (being alfo urged by a violent wind at weft) with uncommon rapidity; the confequence of which was, that the four caiffon piers, totally unguarded except as above-mentioned, were all underwafhed at the weft end, to the depth of about 15 inches at a medium, at the borders, and fome to a greater breadth and fome lefs; but the pier that had the half girdle courfe round the weft point having been found to fuffer along with the reft, though not in fo great a degree, this induced Mr. Smeaton to think of a mode of defence not merely terminating upon the upper cruft of the gravel as the girdle ftones (which this event fhewed was not fufficient to refift the increafed velocity of the current, when paffing by a new object), but inftead of the girdle ftones, to go fome depth into the gravel; which it appeared practicable to do, by driving a cafing of plank piles to furround every caiffon pier at the diftance of three feet, which would alfo enable him fafely to underpin the parts underwafhed.

To this propofition (though attended with an addition of expenfe unthought of before, of between five and fix hundred pounds) Mr. Donkin very readily confented on the part of Mr. Errington. This was therefore immediately put in hand before further proceedings were gone upon.

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It may be proper to mention that when the firſt caſing was completed, which was about the fifth pier from the north ſide, Mr. Smeaton ordered a trial to be made to pump out the water, which, if practicable, would have afforded the moſt eaſy way of underſetting the under-waſhed parts; but this being attempted, Mr. Pickernell reported, that with four double pumps and two ſingle ones they had not been able to ſink the ſurface of the water within the caſe above an inch below the ſurface on the outſide. In this method, however, the coffer-dam caſes uſed at Perth Bridge were driven ſo as to keep the water out of the foundation pits, when the ſurface of the river (when the tide was in) was from ſix to ſeven feet deep upon the bed of the river, and conſequently againſt the ſides of the caſing, it would therefore have ſeemed that there had been ſome very palpable defect in driving theſe caſes, had not the operations at the ſecond pier from the north ſide ſufficiently ſhewn how extremely open the bed of gravel is to the paſſage of water, and how impracticable every method was likely to prove that depended upon the drainage of the water, for the piers to be placed in the main channel of the river.

Several very rapid and much larger floods than that which did the miſchief happened in the courſe of the ſucceeding winter, particularly one upon the 12th of December, when the water was within nine inches of the top of the inpoſt; when Mr. Pickernell marked a fall of two feet three inches, but without any material damage to any thing, which naturally induced all thoſe concerned to proceed in the way they were then going on.

The ſeaſon of 1779 was begun by new founding the weſtern half of the pier, that the weather prevented from being completed the year before, which was the fifth from the north, and was done without caiſſon or draining the water, by means of an air cheſt or diving machine, that had been very ſucceſsfully and conveniently employed in underſetting the other five damaged piers; and the pier before unbegun (being the fixth from the north) was the next in courſe founded by caiſſon; but with this difference, that the caſe was firſt drove all except the down ſtream ſalient pointing, before the caiſſon was floated into its place through this opening.

It would cauſe too great a prolixity to deſcribe the particular operations of what followed the diſaſter of Auguſt 1778; nor can they be done without reference to figures; I ſhall therefore proceed to ſay that in the beginning of the year 1779, and alſo afterwards while the arches were throwing, the whole of the caſes were guarded all round by a depoſition of rubble; and to render it the more effectual againſt the torrents that this river then appeared ſubject to, the up ſtream points of the rubble bulwarks were extended to the length of 30 feet above the ſalient point of the caſes reſpectively.

That

That the underſetting of the three piers ſo treated, was done ſo as to be as ſolid and effectual as the gravel ſtratum which the whole ſtood upon, as alſo the new founding of half of the fifth pier, and the original founding of the ſixth, which was the laſt founded; and that the whole ſtood upon one bottom equally capable of ſupporting the weight of the ſuperſtructure built upon it, appears from this, that in the whole of the maſonry, from the time of the accident in 1778 to the time of its total overthrow in the year 1782, there never appeared the leaſt crack or ſet in any part of the work, not even in the parapets, which to thoſe who are well experienced in bridge-building, will appear a remarkable inſtance of the ſoundneſs of the work; and furthermore, that the whole was ſufficiently guarded againſt every accident that could be foreſeen or expected appears from this; that in the year 1779 a remarkably rapid flood happened: which Mr. Pickernell obſerved, from marks upon the bridge, above and below, ſhewed a fall of three feet nine inches, occaſioning a velocity of above 900 feet per minute, which not only paſſed without any material derangement; but, on the contrary, ſuch changes as had been made in the bed of the river had been for the better, as it had acquired a more equal depth from ſide to ſide; the ſhallow parts becoming deeper, and even the deeper parts, by the depoſiting of gravel, had become ſhallower, and every flood that happened after, occaſioned reports of the ſame kind till the laſt. In this manner, and with theſe ideas, every thing was ſatisfactorily finiſhed, and the rubbling completed, according to Mr. Smeaton's directions, at or about Chriſtmas 1780; and in the beginning of January 1781, Mr. Smeaton viewed the whole, in the preſence of the magiſtrates of the county, who attended for that purpoſe, and found every thing done to his great ſatisfaction as well as theirs; and as ſuch reported it to the county, as being completed according to Mr. Errington's agreement.

After all ſucceeding floods, every account was of the moſt flattering kind; ſo that previouſly to the laſt flood, every perſon concerned therein or therewith ſeemed perfectly eaſy as to the ſecurity of Hexham Bridge.

On Sunday evening the 10th of March 1782, there happened in that country a great downfall of ſnow, ſo great as to be a foot thick upon the plain ground; which was immediately ſucceeded by a violent hurricane: and as the nature of ſnow is to drink up the rain like a ſponge, till it becomes perfectly ſaturated with water, it then burſts at once like a ſnow-ball in the fire, and may be fitly compared to an immenſe reſervoir, extending over the whole country, and breaking looſe altogether; and as the hills, and whole face of this country, are ſteep, comparatively like the roof of a houſe, the water is capable of coming down very ſuddenly; it then meets altogether, by the junction of the two Tynes, a little above Hexham, without having any conſiderable flat ground to ſpread itſelf upon. The next morning, viz.

viz. Monday, March 11th, Mr. Donkin perceiving an extraordinary high flood in the river (which runs from weſt to eaſt) attended with a very high weſterly wind, he was led to go down to the bridge, to obſerve the effects of the water upon it; but without the leaſt ſuppoſition of any damage happening thereto; when he obſerved, that the water was up to the top of the dooming (as there called), that is, the tops of the caps of the ſalient points upon the piers of the up ſtream ſide of the bridge, when it ſcarcely touched the down ſtream ſide, which makes a difference in level in paſſing the bridge of no leſs than between four and five feet, and which, according to the known rules of hydraulicks, will occaſion a velocity of one thouſand feet in a minute; but yet he was ſo far from apprehending any danger to the bridge, that he had juſt ſent his ſon over it, to the ſouth end, with two or three maſons, to examine the ſtate of the land-arches there, who reported all ſafe, but they had not returned above five minutes, before he began to obſerve ſymptoms of failure, when to his great ſurprize, " he perceived ſome particles of lime fall from the fourth arch, about " the ſize of chaff, and the lime coming from thence and no where elſe, he pointed his " obſervations to that part only. That the falling of the lime continued to encreaſe in " ſize and quantity, for the ſpace of a minute; that ſoon after he obſerved a crack acroſs " the bend of the arch towards the upper ſide of the bridge, which crack gradually " widened, and in about a minute more, the ſplinters from the ſtones in the plain part of " the ſpandrel, between the third and fourth arch, which he could perceive ſhake, gave " way, and the two arches and a pier fell together; that the whole bridge was deſtroyed " in half an hour," only two arches remaining whole, and one fell in part in the evening. Such was the ſudden cataſtrophe of this much commended unfortunate bridge.

The ſecond queſtion is, Whether Mr. Errington was ſparing of any thing neceſſary to give ſucceſs to that mode of building, which Mr. Smeaton had adopted?

To this Mr. Smeaton can only bear his teſtimony, that he was not; nor did he ever hear him find fault with any expenſe, thought neceſſary by Mr. Smeaton; on the contrary, he always expreſſed his wiſhes to have the bridge completed in the moſt ſubſtantial and effectual manner. Nor did he ever appear diſquieted by the diſaſter of 1778, or at the expenſe of what Mr. Smeaton had propoſed as a neceſſary addition, though at ſo conſiderable an increaſe as five or ſix hundred pounds, as has been already ſtated.

Thirdly, reſpecting Mr. Pickernell, whether he did to the beſt of his power and knowledge, execute to a reaſonable and poſſible extent, what was directed by Mr. Smeaton? And to this Mr. Smeaton thinks it but juſt to ſay as a witneſs, that he always looked on Mr. Pickernell throughout the whole proceeding, as a perſon particularly attentive to execute

execute orders and directions given by him, and upon whoſe capacity for that purpoſe, he could ſafely rely, after having ſhewn him the mode of going about any new operation, and upon whoſe reports of theſe operations, he could alſo ſafely rely; and as the general workmanſhip of the bridge has been applauded by many, and diſcommended by none, it ſeems there is only one point in which Mr. Pickernell's execution of Mr. Smeaton's orders can be called in queſtion, and that is reſpecting the driving down of the caſes of piles, round the caiſſon piers, to a proper depth; it is therefore neceſſary to ſtate this matter particularly.

Mr. Smeaton's written inſtructions were as follow; " The length of the piles ſhould " conform to the depth of the water; I would not wiſh the ſheeting piles round the weſt " end, and the firſt bay of the return on each ſide, to go into the ground more than " about ten feet, and if they do not drive kindly, muſt be contented with leſs; from " thence, each bay may be gradually leſs depth into the ground, ſo that round the down " ſtream pointing ſeven feet will be ſufficient. If the gage piles drive kindly, they may " be longer by eighteen inches or two feet than the ſheeting, but if not, they need not " be above one foot longer."

To the above, in the courſe of the work, Mr. Pickernell reported, that having driven the piles of the fifth pier from the north, which was the firſt to which the caſing was applied, the gage piles went down very well and entered two or three inches at a ſtroke, but when he came to drive the plank piles, they could not be got into the ground more than from five to ſeven feet.

He further reported in the courſe of this buſineſs, in regard to the ſheet piling of the ſeventh pier from the north (or ſecond from the ſouth ſide) which was the laſt caſing driven of the four damaged piers; that the bed of the river at the ſouth ſide, is entirely full of large flat ſtones, ſuch as they got out of Oakwood bank quarry, which have been the ruins of the boats' landings, taken away by floods and ice from time to time, and thoſe ſtones had obſtructed their ſheet piling round that foundation, and had occaſioned many of them to go out of their places at bottom, ſo that ſundry cavities were occaſioned thereby, more than in the laſt.

Theſe were the repreſentations of Mr. Pickernell, concerning his execution of Mr. Smeaton's orders, reſpecting the piling; ſo that if they were driven to a leſs depth, or in any manner leſs effectual than as above repreſented, Mr. Pickernell muſt anſwer to it, as Mr. Smeaton was totally unacquainted therewith, nor was any inſufficiency in this part of the

the work ever ſuggeſted to him by any perſon whatſoever during the courſe of the work, or ſince, till he heard of an oppoſition to Mr. Errington's bill for relief from his obligation.

But whether in reality Mr. Pickernell did this part of the work equal to the above repreſentation of it or not, that the ſtanding or falling of the bridge may not be wholly left to reſt at Mr. Pickernell's door, Mr. Smeaton, in juſtice to Mr. Pickernell as well as himſelf, thinks it neceſſary to declare, that for the reaſons already aſſigned, (as well as the verification thereof during the courſe of the work, by every flood that happened) ſo great and abſolute was his dependence upon the application of Oakwood bank quarry rubble, as an ultimate defence to controul the violence of the Tyne's floods (no part of it having ever been moved); that provided the piles laid round the coffer dam foundations, of the caſings were but driven into the ground, ſo far as to fix faſt therein, and ſo cloſe together, that though the caſes might not hold water, they might retain the gravel from being waſhed out through the chinks from under the piers; he had not the leaſt doubt of preventing any material damage ever being done to the pile work, by the application of the ſaid rubble to ſurround them. This ſentiment, however, though it dictated that part of his inſtructions, "get the bays of ſheet-piling at the weſt end of the piers down to "ten feet if you can, if you cannot, we muſt be contented with leſs;" and alſo made Mr. Smeaton contented with what was above reported to him, as the moſt imperfect part of the performance; yet he never communicated this opinion to Mr. Pickernell, or any other perſon; leſt the workmen from hearing thereof, might be induced to ſatisfy themſelves with doing leſs than otherwiſe they might be capable of, in the way of getting them down as far as they could.

Whether Mr. Smeaton's opinion, concerning the ſecurity of Oakwood bank quarry rubble, was well or ill-founded, will be further examined in the ſequel; but this is certain, that the driving of the caſes not being completed before the middle of September, and being then very deſirous to take advantage of the ſecurity they afforded, to get the piers underſet, if poſſible, or otherwiſe ſecured before the heavy winter floods came on, he concluded, that if the experience of theſe floods ſhould ſhew a need of greater ſtrength and defence, it might be added in the courſe of the next ſeaſon.

This autumn of 1778, in reality, afforded the experience of a conſiderable number of floods, amongſt which, the laſt, which was of December 12, was a capital one, and the higheſt that had been ſince the great inundation of 1771; and the water on the weſt or up ſtream ſide of the bridge, was within nine inches of the top of the impoſt of the ſecond pier

pier from the north, when at the eaſt end it was one foot three inches below it, ſo that the fall was then no leſs than two feet three inches, and which would produce a velocity of above ſeven hundred feet per minute.

After the water was ſubſided ſo as to afford a full examination, Mr. Pickernell reported the effect; viz. that there were but very few of the rubble ſtones removed from where they were thrown in round the foundations; what were moved, were from the weſt ſhoulders; but that from the third pier to the north, round which no ſtones had been depoſited, it had torn up the gravel from the ſalient point and weſt ſhoulders, to the depth of three feet; and that from thence to the ſtones that were laid round the ſecond pier, it had deepened the bed of the river full eighteen inches, (which before was too ſhallow); but as to all the other part of the river's bed, he could not perceive it altered in the leaſt.

The experience therefore of theſe floods, and particularly that of the 12th December, all concurred in proving, that the Oakwood bank quarry rubble was a ſufficient defence againſt every violence of the Tyne: ſo that it did not appear neceſſary to introduce any new mode of defence, but only to apply the rubble in the moſt effectual manner; and as the weſt ſhoulders appeared to be the parts that the greateſt ſtreſs came upon, Mr. Smeaton ordered that the water might not meet with ſo ſudden an oppoſition there, but be more evenly, ſlopingly, and gradually brought thereupon, that the weſt ſalient points of the rubble ſhould be extended weſtward of the ſalient points of the caſes reſpectively, to the length of at leaſt thirty feet; which was accordingly executed by Mr. Pickernell upon all the caiſſon piers.

4thly, We come now to the fourth and laſt queſtion, viz. Whether under all the experience and knowledge of the ſubject as it now ſtands, the preſent bridge ſhould be attempted to be reinſtated, or a new one built at Hexham?

This queſtion is indeed of far the moſt material import; for it is of little conſequence to the public, in the preſent ſtate of things, whether Mr. Smeaton miſjudged of the ſubject? Whether he was deceived himſelf, or was deceived by others? Or, whether Mr. Pickernell did or did not do his beſt, towards a full execution of Mr. Smeaton's orders, in regard to the driving the caſing piles? Nor is it of any conſequence to know, that in point of art, but without any regard to, or limitation of expenſe, a bridge is poſſible to be built: the true queſtion is, Is it fitting for the county to undertake it? Suppoſing the Treaſurer in poſſeſſion of whatever ſum can be recovered from Mr. Errington, in conſequence of his obligation, will it not (like Sir Walter Blackett's three thouſand pounds)

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pounds) be a temptation to the county to ſpend ſtill much larger ſums upon an unfruitful project; and it may reaſonably be ſuppoſed, that the whole county ſtock is not an unlimited ſum; nor can it be properly expended in the erection of a bridge at one ſingle paſſage.

It is now known for a certainty, what was not, and could not have been known before the erection of this bridge, that there is a poſſibility of natural cauſes being ſo combined, as to produce a flood ſo large, and of ſo ſudden a nature, as to produce a velocity of the water exceeding one thouſand feet in a minute; and whether even this may, or may not, be the uttermoſt limit of Nature, is not in the power of any man to calculate:—

That the velocity of ſeven hundred and twenty feet per minute, ariſing from a difference of two feet three inches, as per flood of December 1778, was ſufficient to tear up and remove the natural bed of gravel, which forms the bed of the river in this place, wherever there was a particular ſet upon it, but was not cabable of moving or materially deranging the defences compoſed of Oakwood quarry rubble.

That the velocity of nine hundred and thirty feet, reſulting from a difference of three feet nine inches, in a flood of the 1ſt of December 1779, ſtill made not the leaſt alteration in the defences, nor to any part of the bed of the river, ſave that the rubble ſtones depoſited at the third pier where the current had torn up the natural gravel in the flood of December 1778, were now wrecked full and covered with gravel, and reduced to the level of the adjacent parts. Another flood ſucceeded this in the compaſs of ten days, that roſe within eight inches as high as the former, but in this nothing happened of any kind; in ſhort, the bridge being now erected, as far as it was concerned with the water, all the arches cleared, and the defences completed, after a conſiderable number of great floods, and nothing happening in conſequence, every one ſeemed ſo entirely ſatisfied of the ſtability of the bridge, that even the Gilligate people, Mr. Pickernell obſerved, ceaſed their viſits, who before had conſtantly, after every flood, come to inſpect, in hopes of finding ſomething correſpondent to their prayers and wiſhes for the downfall of the bridge.

Mr. Smeaton was, however, agreeably ſurpriſed on having this account, that the fall of water had been ſo great, and no harm enſued; for had it been poſſible for him to be appriſed of ſuch a fall before hand, he never ſhould have recommended to Mr. Errington to have undertaken to erect a bridge upon that bed of gravel.

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It therefore at this time appears plain, that though the Oakwood bank rubble will lie ſtill, and reſiſt a velocityof the water of nine hundred and thirty feet in a minute,yet it is capable of being all removed and carried away by the velocity of the water of, or a little exceeding, one thouſand feet per minute; a velocity reſulting from a difference of forty-four, as it was or upwards in the flood of March 1782; and that the gravel bed itſelf is capable of being torn up by a much leſs degree of velocity; the queſtion then is, How in ſuch ſituation a foundation can be laid and effectually ſecured?

Shall we attempt to build a wall acroſs the bottom of the river, according to Mr. Wooler's propoſition? Experience has ſhewn in the building of the laſt bridge, that the gravel is of ſo open a nature in the main channel of the river, that it is impracticable to drain off the water. Mr. Smeaton means not to put limits to the invention and ingenuity of men; but neither his obſervation, experience, nor invention, has hitherto ſuggeſted any effectual method of founding ſuch a wall, without draining off the water; and the ſame will apply to the penning the bottom acroſs the river.

But for a moment, ſuppoſe the thing done: this wall or this apron, muſt have a termination; and wherever it terminates, experience ſhews, a rapid current will form a deep hole, to twenty, or even thirty feet depth, and upwards; and if the gravel under the foundation gets looſe, the downfall of the whole is the conſequence.

2dly, Suppoſe we attempt to build it in an excavation upon piles encaſed, as was done at Perth, the ſame difficulty ariſes; we cannot get out the water; and if done, as rubble will not lie to defend it, the gravel bed being ſcooped out, beyond all practibility of driving piles, the piers being ſapped, the ſame unfortunate circumſtance muſt enſue.

3dly, Suppoſe we attempt it by excavation with ballaſt lighters, and drive down piles even with the bottom of the excavation pits, to found the piers upon; which may doubtleſs be done, without taking off, or drainage of the water; ſtill, if neither the bed of gravel itſelf, nor quarry rubble, is capable of reſiſting the violence of the current, when the gravel bed is deſtroyed or deranged, ſo that the piles are laid bare, the pillars will be ſapped, and deſtruction equally enſue: nay, even ſuppoſe the piles could be encaſed without taking off the water, yet this is only giving the river a little more work to do; for if rubble is carried away, as we find it muſt be, it is no defence; and we do not know the depth to which the gravel can be ſcooped out and excavated by the violence of this river;

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the foundations therefore, however deep, can be ultimately ſapped, and the ſame ruin enſue.

In ſhort, turn ourſelves which way we will, nothing ſeems certain in this buſineſs, but a very great expenſe, how commenſurate with the county's funds, muſt be left to thoſe to judge of who know them: but this Mr. Smeaton will take upon himſelf to ſay, that he ſees no way of making foundations for a bridge to ſtand upon, for the whole ſum in which Mr. Errington ſtands obligated to the county, that is likely to be attended with any certainty of permanency, much leſs alſo to build a bridge upon thoſe foundations, for the ſame ſum.

THE following is a Copy of a Paper delivered at Northumberland Aſſizes 1783, by Henry Errington, Eſq., to Gawen Aynſley, Eſq., Chairman for the County of Northumberland, but which appears to have been originally intended to be delivered to the Grand Jury, which had been previouſly diſcharged, as the Words Gentlemen and Magiſtrates, in the Original, are ſubſtituted for Grand Jury.

MR. ERRINGTON'S contract with the Juſtices of the Peace reſpecting Hexham Bridge having placed him in a very diſagreeable ſituation, he, as well on his own account as on the part of the County, wiſhes the Gentlemen and Magiſtrates, now aſſembled, as a reſpectable body of the County, would be pleaſed to take the following ſhort ſtatement of facts into their conſideration.

Mr. Errington undertook to build the bridge according to a ſpecific plan, under the direction of Mr. Smeaton, and to uphold, ſupport, repair, maintain, rebuild, and keep it in good and ſufficient repair for the term of ſeven years, to be computed from the time it ſhould be certified under the hands of two juſtices to be ſo built.

The bridge being completely finiſhed according to ſuch plan and direction, was in January 1781, certified for.

The

The plan to which Mr. Errington was confined, was not only a plan of the ſuperſtructure, but alſo of the foundation, and of the manner in which ſuch foundation was to be laid.

In March 1782, the bridge was thrown down, from which circumſtance it is evident, that to rebuild it according to the ſame plan would be ineffectual, and from the nature of the contract, it is not in the power of the contracting parties to alter or vary it; indeed, Mr. Smeaton, whoſe direction Mr. Errington was bound to obey, has declared that it is not in his power to deviſe a better. If therefore the County ſhould inſiſt on Mr. Errington's rebuilding the bridge, a great portion of the ſeven years would expire before he could complete it; (two years and a half having already elapſed ſince the certificate)—and if by favourable ſeaſons it ſhould be capable of being upheld till the end of the ſeven years, he would then be diſcharged from his obligation, and the burthen would fall upon the County; Mr. Errington in common with the land owners of the county in general, and by having an eſtate in the vicinity of Hexham in particular, feels himſelf intereſted in having a bridge built, which by an alteration in the mode of ſtructure may be attended with a probability of being permanent, and he has been informed that other engineers lately conſulted by the Juſtices are of opinion that it is practicable; he, therefore, conceives that it would be more advantageous to the County to accept from him ſuch ſum of money as ſhall be eſtimated equal to the expenſe of repairing the bridge, and putting the ſame into ſuch a ſituation as his contract requires, and apply ſuch ſum together* with the materials, (which are of more than four times the value of thoſe received by Mr. Errington from the County), towards building a new bridge according to ſome other plan, than to require him to repair the old one upon the former erroneous principles. — And if the Gentlemen and Magiſtrates ſhould be of the ſame opinion, Mr. Errington doubts not the Juſtices will, as truſtees for the public, readily adopt what ſhall ſo appear to be the ſenſe of the County.

	£
* Value of materials received by Mr. Errington from the County, and acknowledged by him to be eſtimated at - - - - -	3000
Which multiplied by 4 - - - - -	12,000

Which is 2900l. more than the penalty of Mr. Errington's bond to the County, and many thouſands more than expended.

Mr.

Mr. MYLNE's Second Report.

Edinburgh, 30th September 1783.

To the Magiſtrates and Juſtices of Peace for the County of Northumberland, &c. &c.

Gentlemen,

A PAPER has been tranſmitted to me by Mr. Davidſon, Clerk of the Peace, which contains a propoſition from Mr. Errington to pay a certain ſum (to be fixed hereafter) in lieu of rebuilding Hexham Bridge; and he requeſts me, by directions of Mr. Aynſley, the Chairman, to ſend my full ſentiments thereon, to be laid before your meeting of the 8th October next.

As it will be convenient for me to attend you at the ſaid meeting, I apprehend it is not neceſſary to ſay much on this occaſion; other than ſtating a few words on ſome matters of fact, which require to be aſcertained, before any one can judge with certainty and preciſion. Another reaſon requires me to be the more conciſe at preſent, as in the event of not agreeing with Mr. Errington, and the ſubject being diſcuſſed at law, every previous animadverſion would in that event be ill timed and premature.

The ground work of the propoſal, and the propriety of the reaſoning which it contains, depend upon the following matters:

1ſt, It ſtates that the agreement was to build according to a ſpecific plan.

2dly, To do that under the direction of Mr. Smeaton.

3dly, That it was completely finiſhed according to ſuch plan, and under ſuch direction. And

Laſtly, That he was confined to ſuch ſpecific plan; which was not only a plan of the ſuperſtructure, but alſo of the foundation part; and of the manner in which ſuch foundation was to be laid.

On the firſt head, it will appear, that all the foundations were, by the plan annexed to the articles of agreement, to have been laid full five feet below the water line, in maſonry or timber framed work; and the two abutments, and the two piers next the abutments,

ments, are propoſed to be piled in ſuch manner as ſhall appear neceſſary on opening the ground.

In all other reſpects whatſoever, either as to the quantity or quality of the piling under theſe parts ſo mentioned, and under any part of the other eight piers, or of any manner whatſoever of laying all or any of the foundations, the plan does not hold forth any ſpecific manner of laying the foundation; but on the other hand, leaves all theſe particulars to the judgment and adoption of the contracting party.

On the ſecond head, the agreement entered into on the propoſals of Mr. Errington and his agents, was certainly to put the whole under the direction of Mr. Smeaton; and the act of parliament which followed thereupon, confirms it to a certainty not to be ſhaken. The reference thus to be held to the judgment of Mr. Smeaton, was in no points more evidently neceſſary than in the manner of laying the foundations, which were not ſpecified at all, as well as in many other things impoſſible to be contained in drawings, written agreements, or in acts of parliament. But, in the unfortunate event of things, I conceive, the operation of Mr. Smeaton's directions in all matters not ſpecified as above mentioned, he was led aſtray, and that his directions were not followed. Proceedings which were eaſy in their nature, were followed up with a fatal rapidity, that laid the ſeeds of ruin; and the guard works, which were added, on after conſideration, and the experience of the ſhallowneſs of the foundations, were not executed conſiſtently with the correctneſs and good ſenſe of his orders.

His directions I conceive to have been clear and ſufficient if they had been fulfilled; his candour will not allow him to ſay thus much; a commendable regard to others engaged in the executive branch, ſuppreſſes what ought to be ſaid: but I who feel for the character and reputation of ſo great an artiſt, and every man ſo peculiarly ſituate as he is, muſt be permitted to ſay, that the purport and effect of his directions were not executed, and of courſe, that he was deceived.

On the third head, it is neceſſary to ſtate that the foundations were not laid according to the plan, ſo far as the ſpecification thereof went. To begin at the north end, the butment is not ſo deep as ſhewn by the drawing by two feet; the firſt pier by three feet five inches, the ſecond pier by two feet four inches, the third pier by two feet eleven inches, the fourth pier by ſeven inches, the fifth pier was ten inches more in depth than the plan, the ſixth pier was in like manner eleven inches, the ſeventh was alſo ſix inches, the eighth pier is two feet ſhort of its depth; and the ſouth butment is two feet in like manner leſs than it ought to be.

From

From this ſtatement, founded on the beſt evidence I could procure, the bridge was not built according to the deſign agreed on where it could have been; and that the directions given were not followed literally and effectively.

On the laſt head, I have ſufficiently ſhewn that the ſpecification of the plan did not confine the bridge in manner of laying the foundations, nor in the ſhape and extent of the works. Anything might have been done under the agreement, which a more intimate knowledge of the bed of the river, and the experience of the works themſelves, gave, during the time of the execution: in fact, it is ſhewn, that the parts ſpecified were altered and modified to ſuit the manner adopted for the execution.

The concluſion, therefore, naturally draws me to end with ſaying, that no argument can be reaſonably built on the idea of being confined to a ſpecific plan agreed for, or executed in thoſe parts, to wit, the foundations, on which this queſtion depends. And I am thoroughly convinced that if Mr. Smeaton, poſſeſſed as he is of ſo much ſtrength of judgment and variety of reſources, were to view the work and examine its preſent ſtate, with a view to its repair, he could with ſatisfaction to himſelf undertake to reconſtruct the bridge according to the agreement, with the ſame expectancy of permanent durability as he had at firſt ſetting off with this undertaking.

What remains to be ſaid will come better into the diſcuſſion which is propoſed to be held at your intended meeting; until which time, I remain,

Gentlemen,

Your very humble and much obliged ſervant,

ROBERT MYLNE.

OBSERVATIONS on Two Reports of Robert Mylne Eſq. concerning Hexham Bridge, by J. SMEATON, Civil Engineer.

THERE are ſo many points contained in the two reports of Mr. Mylne, of the 24th April and the 30th September 1783, in which I entirely differ with that gentleman in opinion, that to make the proper obſervations upon the whole, would draw me out to a length that in the preſent ſtate of things I would wiſh to avoid. I ſhall therefore content myſelf with obſerving upon thoſe that I look upon to be the foundation of that difference of opinion; and upon which the merits of the queſtion ſeem principally to depend. I ſhall therefore paſs over the compliments that Mr. Mylne's politeneſs prompts him to pay me on this occaſion; and particularly as they ſeem to be at my own expenſe. For the greater eaſe of reference, I ſhall apply to the printed copy of Mr. Mylne's reports.

Mr. Mylne ſays, page 5th, (298 of this volume) "The exiſtence of a ſand below, and a "ſuppoſed hardneſs and concretion of five feet, or any ſuch meaſure of the upper parts, "ſeem to have precipitately and fatally determined the plans of operation at firſt ſetting "out; and appear to me to be equally the cauſe of the preſent precipitate opinion for "abandoning the work as impracticable."

He alſo ſays, page 4,(298) "Mr. Smeaton, than whom there is no perſon or artiſt better "inſtructed, more knowing, and of a more penetrating and correct judgment, muſt have "been deceived in the collection of facts and materials, on which he eſtabliſhed his plan "of operations."

Now, if in the following detail it ſhall appear that Mr. Smeaton made a proper collection of facts whereon to judge; and did make a proper judgment thereon, ſo far as at the time he was to form this judgment had come to light; then, Mr. Mylne's reflections on this judgment muſt appear unfounded, and will in courſe fall to the ground.

Mr. Mylne acknowledges himſelf to have been made acquainted with the reaſons and motives of Mr. Smeaton; for page 6th,(298) he ſays, "I have ſeen and examined all Mr. "Smeaton's papers, I have heard all the particulars, and hiſtory of his proceedings and "motives for the method of operations, which he adopted:" and Mr. Mylne knows that this intelligence was from Mr. Smeaton himſelf, before Mr. Mylne went down *to examine the works and perſons concerned, and employed in the detail of its execution:* and that it was in this conference that Mr. Smeaton mentioned to him, that the ground and reaſon which influenced his judgment in not ſinking the piers of the bridge deeper into the bed of the river was an eſtabliſhed opinion that the greateſt part of the river's *bed* conſiſted of a gravel, very hard compacted together and difficult to penetrate at its upper ſurface; but which diminiſhes in compactneſs from the ſurface downwards; ſo that at ſome depth exceeding five feet, it deviated into a ſand, and ultimately into a quickſand or mud. The exiſtence of ſuch a ſand below, as alſo a ſuppoſed hardneſs and concretion of five feet, *or any ſuch meaſure*, of the upper parts, Mr. Mylne explodes in the terms already quoted: but as herein reſides the foundation of that entire difference of opinion that ſtill ſubſiſts

fubfifts betwixt Mr. Mylne and Mr. Smeaton, it feems proper now to examine the grounds whereon Mr. Smeaton eftablifhed this opinion, and alfo the grounds whereon Mr. Mylne explodes it; becaufe, if well founded, from what *appeared at the time*, it muft be admitted fufficient in reafon for Mr. Smeaton's determining his plan of operations according to it, though, fince the fatal accident, any thing fhould appear to the contrary; and if on the other hand, from any thing that can be deduced from M. Mylne's operations, Mr. Smeaton's original conclufions ftand uninvalidated; then it muft appear, that Mr. Mylne muft have been drawn into a precipitate opinion, or, as he terms it, *deceived*.

That Sir Walter Blackett built a bridge at Hexham, which not long after it was finifhed, was thrown down by the great flood in 1771, in one night, and the materials almoft totally difperfed, is an event too notorious for Mr. Smeaton to be *deceived* in.

That the foundations of this bridge were let into the bed of the river, well founded upon a great number of piles, and a platform upon the heads of them 12 inches thick, of folid balks judicioufly rabetted together, Mr. Smeaton could not be *deceived* in; having been eye witnefs to many of the operations.

That all the piers, arches, and one of the two abutments were totally deftroyed, and the whole length of one fide of one of the platforms raifed out of the water, half way between the horizontal line and the perpendicular; in this alfo Smeaton could not have been *deceived*, having feen it for feveral years together; and was expofed to the full view of every one that paffed by.

From the above facts, Mr. Smeaton inferred, that though the upper cruft was hard gravel, yet a much more foft and yielding material lay underneath it, otherwife the bottom, could not have been turned up in the manner mentioned, and that the foundations would have been more fecure, had they been laid upon the upper cruft without its being broken, by excavating or driving piles: and which is evidently proved by the fubfequent operations that now come in courfe to be mentioned.

That after this accident Sir Walter Blackett, chufing rather to forfeit the penalty of the bond*, in which he was obliged to uphold the bridge for feven years, than to attempt it again, the magiftrates of the county employed Mr. Wooler, then an eminent engineer, to begin another bridge near the fame place: and that in confequence he built a land-

* Penalty 3000l.

breaft

breaft on the north fide; and many preparations being made, and every thing ready for founding a pier, upon the fame fide; on digging the foundation put into the bed of the river, the whole work was put a ftop to for fome reafon or other; and in this Mr. Smeaton could not be deceived; becaufe at that time he was often at Hexham, was well acquainted with Mr. Wooler, and faw the operations going on, and afterwards difcontinued: and it will be further proved by living evidence, that the reafon for difcontinuing the work, was the *foftnefs* of the bottom of the foundation pit; and to afcertain whether this foftnefs was particular to *that place*, a pit within the folid bank was dug upon the oppofite fide of the river, in the bottom of which the fame foft ftratum prevailed; and to this fome of the magiftrates were themfelves witneffes, as will alfo be proved: it can alfo be proved from a letter of the faid Mr. Wooler, now deceafed, that in his opinion *a permanent bridge could not be eftablifhed here without building a folid wall of fix feet high, and 42 broad, quite acrofs the river;* which he obferved was an expedient that has fucceeded where *expenfe was not regarded.* He further fays, " that the attempting to fet a bridge " upon fuch an enormous depth of quickfand, over a river fo fubject to floods as the " Tyne, may be deemed fo hazardous as to be next to imprudence itfelf."

Mr. Smeaton therefore could not be *deceived* as to the exiftence of a hard ftratum of gravel at the top, with a quickfand under it, at either of the places juft defcribed*: as Mr. Wooler's operations fully prove what was the caufe of the failure of the firft bridge.

Mr. Jonathan Pickernell, who was brought from London to be employed in this bufinefs under Mr. Wooler, and recommended by him, will further prove, that he was employed to bore the river, which he did in various places, and verbally reported to Mr. Smeaton, that wherever he had tried the river he conftantly found a quickfand to take place underneath the upper bed of gravel; and that he had reported the fame to *the clerk of the peace*.

In this Pickernell might have deceived Mr. Smeaton; in his never having made fuch borings, nor made fuch report: but Smeaton did not reft it here; for in the very place where he built the bridge, he tried the bottom of the river, not by boring, but by driving down a pointed iron bar, in various places acrofs the river, to the depth of nine or ten feet, and conftantly found, that though the entry of the bar was in all places difficult, yet at every blow it went more and more eafy; however at this depth the gravel felt fo tolerably compact as

* N. B. The Dwarf wall, the place recommended by Mr. Mylne, is near the original bridge.

to

to be deemed by him sufficient for supporting a bridge, *provided* the upper cruſt was not *broken by digging or piling*; and provided, the weight upon each pier was not *too great*, which would be the conſequence of *wide arches*; and as was the caſe with Sir Walter Blackett's bridge: the middle arch being 70 feet.

Now, if in the concluſion I drew from thoſe trials of the river's bottom by the bar, I have been deceived; I deceived *myſelf*, as I was not beholden to the *patience and perſeverance* of Mr. Pickernell only, for as I not only directed but aſſiſted in the operation myſelf, I ſaw with my *own eyes*, and felt with my *own hands*.

Theſe are the facts on which Mr. Smeaton built his plan of operations, which facts, if valid, he challenges Mr. Mylne to ſhew, that the methods he grounded them on, were not the moſt likely, *as far as was then known*, to produce a permanent bridge, that if, at all, muſt be erected at ſuch a moderate expenſe as the county of Northumberland was likely to raiſe: for to build a ſolid wall acroſs the river whereon to ſet it, he judged with Mr. Wooler to be improper, except where *expenſe was not to be regarded*.

Let us now ſee what Mr. Mylne has on the other hand eſtabliſhed to invalidate theſe facts. He ſays, page 3d, (297) "I have bored the river at the bridge to the depth of 23 feet "below the latter water level, in a place where I might not be led aſtray by any altera-"tion formed by the ſaid flood in its milder velocity; and I have found under the "teſtimony and perſeverance of Mr. Wake, that the ſoil and texture of the bed of the "river at this place is uniformly a compoſition or congeries of roundiſh and flat ſtones, "gravel and ſand, of equal quality and conſiſtence in the whole of that depth."

Mr. Mylne then cauſed a hole to be bored to the depth of 23 feet into a bed of gravel: but was this the only hole? Mr. Mylne makes no mention of any other. Where did he bore it? Mr. Mylne does not ſay; but contents himſelf with telling us, he did not bore it in a place where the gravel was liable to be diſturbed by the impetuoſity of the river. But does Mr. Mylne think this was ſufficient to determine what the ſoil and texture of that part of the bed of the river was which *was liable* to be ſo diſturbed? Mr. Mylne ſays, page 4th, (297) that the bed of the river "though hard to the touch of boring, and compact "to the eye, and feeling of inſtruments, is wonderfully looſe, and unconnected in its "parts, inſomuch that the bed of the river Tyne ſeems to ſhift and alter its form, extent, "and ſituation with every flood more or leſs; and tearing up at one time to a great "depth that fair moulded and well-laid hollow, which the ſtream had laid for itſelf "upon ſome former occaſion." This was not the part, therefore, that Mr. Mylne choſe to examine otherwiſe than in his mind's eye; he choſe a place not ſo liable to alter, although the greateſt part of the bridge, and particularly that part that firſt gave way, was founded, and obliged to be founded, upon *this fair moulded and well laid hollow*, which the ſtream had *laid for itſelf upon ſome former occaſion*. Now Mr. Smeaton cannot be deceived in this, that it was in this very part where he drove down his bar: it was in the deepeſt part of the river; and all his trials were made in a *boat*, though the river was then in its low ſtate. Whereas it will be proved in evidence, that the part where Mr. Wake bored was upon a dry gravel bed, nearly abreaſt of the place where Mr. Smeaton put down his ſecond coffer dam pier: and where the foundation was actually ſunk into the bed of the river, as deep as it poſſibly could be for water *; in confidence that the gravel bed there was quite as deep as Mr. Wake's boring has ſince proved it to be. The fact was, that Mr. Smeaton's original *plan* and propoſition was to build the land-breaſt and one pier, on each ſide, with coffer dams, ſinking the foundation thereof into the bed of gravel, piling underneath and round theſe works, to as great a depth as ſhould appear neceſſary on opening the ground; and which accordingly were done: but finding, on founding the north land-breaſt, and alſo the north pier, that the gravel bed extended ſtill further into the bed of the river than was at firſt expected, he directed the ſecond pier (oppoſite which Mr. Wake bored), to be laid in the ſame way; leaving then only five of the eight piers to be built in the *fair moulded hollow* to be ſubject to the *vaſt powers* of the *floods* of this river; and this he was under a neceſſity of doing, as he found it impracticable to drain off the water ſo as properly to eſtabliſh the piers upon a foundation of piling: judging it, therefore, the ſafeſt expedient to preſerve the upper ſurface whole, which he found by far the hardeſt, and to found the reſt of the piers by caiſſons upon the bottom of the river, defending the baſis thereof by ſuch outworks as then were in contemplation.

How, therefore, it happens that becauſe at the place where Mr. Wake bored "the "ſoil and texture of the bed of the river is uniformly a compoſition or congeries of "roundiſh and flat ſtones, gravel, and ſand, of equal quality and conſiſtency throughout the whole of that depth;" it is and muſt be ſo everywhere elſe, as well where he did *not* bore, as where he did! or how Mr. Mylne becomes entitled to report that Mr. Smeaton's inveſtigation of a ſand (or ſoft matter) below, and a greater hardneſs or concretion of the matter above, as appeared to Mr. Smeaton, from driving the bar as already deſcribed, is an unfounded idea, Mr. Smeaton cannot ſee to ariſe otherwiſe than

* It roſe ſo plentifully from the bottom as to employ near 40 men at the pumps.

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Now, if in the conclufion I drew from thofe trials of the river's bottom by the bar, I have been deceived; I deceived *myfelf,* as I was not beholden to the *patience and perfe-verance* of Mr. Pickernell only, for as I not only directed but affifted in the operation myfelf, I faw with my *own eyes,* and felt with my *own hands.*

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* It rofe fo plentifully from the bottom as to employ near 40 men at the pumps.

than from an intuitive knowledge in Mr. Mylne that Mr. Smeaton does not pretend to: inasmuch as that Mr. Mylne does not adduce the trial of any experiment whatever from whence that inference can fairly be made.

Mr. Smeaton, therefore, refers it to any impartial person who shall peruse Mr. Mylne's reports referred to, and these observations upon them, whether it is Mr. Smeaton that has been *deceived* in the collection of facts and materials on which he established his plan of operations; or that Mr. Mylne, after hearing every thing that Mr. Smeaton had to offer, has undertaken to judge of works in a condition from whence their original state cannot now properly be judged of; and by examining many persons concerned and employed in the detail of its execution; and relying on those whose judgments were incompetent to the business; that Mr. Mylne himself, in the forming of these reports, has been *deceived* and drawn into a *precipitate* opinion.

I shall now conclude with observing, that had Sir Walter Blackett's bridge fallen in the day-time, when it could have been observed that the rapidity of the stream formed a fall of five feet, or even half of it, I never would have advised either Mr. Errington or the county to have set about the erection of another bridge at Hexham, either upon piles, or in any other method, unless the sum of money to be expended upon it was unlimited. This single fact would therefore, in the present case, have deterred Mr. Smeaton from proposing the building at all, neither was, nor in its own nature could be known, till the flood that proved the sudden destruction of the last bridge; though it had, without the least damage, withstood a flood when the fall was three feet nine inches, in consequence whereof the water would acquire a velocity of about 900 feet in a minute.

And now, being master of these facts by the fatal destruction of this work also, he is unwilling to injure his reputation by the disappointment of others, in attempting to erect another bridge at Hexham upon a limited sum: that post of honor he leaves to be occupied by some more hardy or fortunate adventurer, remembering that a burnt child dreads the fire.

Grays Inn,
28th *June* 1788.

To

To Mr. Donkin.

Sir, Austhorpe 7th Feb. 1784.

As I heard nothing for so long after the sessions, I flattered myself that Mr. Errington's offer had been accepted.

It is, as you observed, now reduced to this, that Mr. Errington must either rebuild or acquit himself by law; but it is well worth very seriously weighing, whether, to avoid the disagreeable uncertainty of a law-suit by rebuilding, Mr. Errington will not as certainly incur the disagreeableness of both rebuilding and a law-suit into the bargain; for it appears to me, from the temper and disposition of his opponents, that they will dispute every step that he takes, and if they so conceive it not to be *strictly* done in conformity with the contract, he will be equally liable to be harassed by an action for non-conformity in part, as for non-conformity in the whole. Let us now, therefore, review the ground on which he will stand upon each of these points.

If he lets the matter go to a jury upon a non-compliance to rebuild, I wish Mr. Errington would be advised by the most able genius in the law upon the point; as to me, it very strongly appears, that were I a juryman in the cause, I never could consent to a greater sum in damages to the county (notwithstanding the penalty), than the sum he actually received from the county, because, as it will undoubtedly appear sufficiently in evidence, that for the purpose of reinstating the bridge, the materials now upon the place and in their place, are of considerably more value than those Mr. Errington received from the county, notwithstanding their valuation; and if it be true that the law of England is founded in reason, which the law-men strongly contend, that is, in natural justice, it never can be conformable to either justice or reason, that a sum in damage should be given to the county beyond the sum in which the county is really damnified; because in that case the penalty of the bond would be made to operate as a punishment upon a person who has honestly endeavoured to fulfill his contract, and who in fact has once fulfilled it to the full content of the other contracting party, and becomes obnoxious to a penalty for no other reason but because he has been so unfortunate as to have his work destroyed by an act of Providence, which no human foresight could investigate or guard against *.

* In other cases the law does not extend the penalty beyond the damage sustained, for in the case of the common obligation for money borrowed, though the penalty is for double the sum, yet no more is recovered than the sum borrowed and interest. And why so? Because it would be contrary to reason and natural justice to make a man pay more than he borrowed, merely because he failed in doing it at the day. And I am very apprehensive, that there will not be found a determined case *strictly parallel* to the present, where it has been otherwise determined; and if not, this case being a new one, must stand upon the natural ground of the common law, that is, reason and natural justice.

Mr.

Mr. Mylne may talk of the works not having been founded *deep enough*, and that it is uniformly a ſound gravel, becauſe he found it ſo on a trial in a place where nobody that had a knowledge of the ſituation would have doubted it; but though for argument ſake, it ſhould be admitted for *the preſent*, that the gravel was equally compact to an unfathomable depth *quite acroſs* the river, as in the place where he bored, yet we have now the authority of Mr. Mylne to ſay, that this gravel, though "hard to the touch of "boring, compact to the eye and feeling of inſtruments, is wonderfully looſe and "unconnected in its parts."—If ſo, is certainly unable to reſiſt the violence of the floods of the Tyne, which Mr. Mylne very emphatically confirms further, by adding, "inſomuch that the bed of the river Tyne ſeems to ſhift and alter its form, extent, "and ſituation with every flood, more or leſs, and tearing up at one time to a great "depth that fair molded and well-laid hollow that the ſtream laid for itſelf on ſome "former occaſion." Now this being ſo, to what purpoſe to drive piles into a body of gravel, if that body is itſelf liable to be taken away, into which the piles are driven? It is neceſſary then that this body of gravel ſhould be prevented from moving by the depoſition of ſome matter more compact than the gravel itſelf, to be able to reſiſt the violence of the floods, and protect the ground underneath.

This was indeed done by the depoſition of rubble ſtones from Oakwood bank quarry, which depoſition of rubble is not only in general the moſt effectual method my experience has furniſhed, of protecting a gravel ſoil from the waſh of a violent current, but I eſteem the rubble of Oakwood bank quarry of the beſt quality for this purpoſe that I have ſeen. The works were amply guarded with this ſtone; and ſo ſatisfactorily ſo that I did not think any flood of the Tyne would or could have moved them; and I thought them ſtill the more ſecure after having reſiſted the velocity of 900 feet per minute, without the leaſt derangement, but on the contrary, rendered the whole more even and compacted by the interſtices being filled up ſmooth and even with gravel and matter of a leſſer ſize. Had this defence of Oakwood bank quarry rubble laid ſtill there was nothing periſhable in the bridge to be any cauſe of decay; but a flood comes ſo rapid and ſudden that its velocity, amounting to 1000 feet per minute, was ſufficient to move the defence of the Oakwood rubble, and ſo even and equally was it diſtributed that the failure of all the parts dependent thereon was in a manner together.

Mr. Mylne entertains an idea, that if our works had been founded deeper they would have fared better; and ſo far I agree with him in opinion, that had they been as deep again, they might have ſtood an hour longer: but when we know that the river Tyne is capable on every flood, more or leſs, of tearing up that *fair moulded hollow* (I ſuppoſe he means the channel of the river) to a *great depth*, it perhaps may be very difficult to aſcertain what depth will be out of the reach of its action; nor is this difficulty rendered the leſs by his ſhifting the reſolution of this very difficult queſtion from himſelf to us. I know a part of this river where the water has gulled away its bed (as well as I remember it, on meaſure) to the depth of 24 feet below the low ſtate of the water's ſurface.

I have thought it proper to ſay thus much by way of obviating thoſe hints and ſurmiſes which tend to make it ſeem as if every thing had not been done that could be done in the ſituation.

I come now to conſider what ground Mr. Errington ſtands upon in caſe of rebuilding; and here it ſtrikes me, that not only Mr. Mylne, but every one elſe alſo, has conſidered this matter in the ſame light as if it had never been done, that is, conſidering how Mr. Errington was to acquit himſelf of the whole agreement: whereas the bridge has been built complete, and to the entire ſatisfaction of all the contracting parties, according to the agreement, and ſo certified by two magiſtrates as therein appointed: had, therefore, the laſt covenant been omitted, which obliges Mr. Errington to *maintain* and *uphold* for ſeven years after the magiſtrates' certificate, he would moſt certainly have ſtood acquitted as having fully performed his contract. It would, therefore, ſeem to me, that what remains obligatory in the contract is what remains ſo in force of the laſt clauſe, and it would further ſeem to me, that in an unfortunate caſe, like the preſent, where the thing has once been ſatisfactorily done, that a liberality of conſtruction of this laſt clauſe cannot be extended in disfavor of Mr. Errington, but rather, as far as the nature of the thing will reaſonably admit, in his favour.

I ſhould therefore wiſh that the following queries were ſubmitted to ſome genius in the law.

1ſt, As a conſiderable part of the bridge is left ſtanding and unhurt, whether, if more favourable in point of conſtruction to Mr. Errington, this may not be placed under the idea of an obligation to *repair* in contradiſtinction to that of *rebuilding?*

2dly, Whether the words of the contract *uphold, ſupport, repair, maintain*, and *keep in good and ſubſtantial repair* the ſaid bridge, will oblige Mr. Errington to make the bridge exactly

exactly what it was before, or ſtrictly conformable to the deſign annexed to the contract, and to which it refers, notwithſtanding that from the nature of the accident, the ground of the ſite is ſo altered that an exact reſtitution is now impracticable?

3dly, Whether Mr. Errington (having once acquitted himſelf in point of ſatisfactory conſtruction) is obliged (further than he may think neceſſary for his own ſecurity) to make any additional defences, or to be at greater expenſes in rendering the foundation more ſecure than it was before, but may do the work in the ſame way it was before, where that can be done; and where change of circumſtances has rendered that impracticable, in any other equivalent way, in the judgment of Mr. Smeaton, to whom the whole matter by the agreement has been referred, and confirmed by act of parliament?

4thly, Whether Mr. Errington may not, for his own ſecurity, take any other method of rebuilding any of the particular parts deranged, that from change of circumſtances ſhall be, in the judgment of Mr. Smeaton, more likely than the former to render the work permanent?

5thly, Whether the words *good and ſufficient repair* are not qualifying words which will enable Mr. Errington to make uſe of the old materials in the places where they are now at reſt though not in the ſame poſition in which they were originally built; inſomuch that had the flood turned ſome of the pillars topſy turvy, whether they may not be made uſe of in part of the re-erection, provided that, in the judgment of Mr. Smeaton, they are or can be rendered as ſecure as in the original conſtruction; though in point of poſition they will not be ſtrictly conformable to the original deſign referred to, but will be made as ſafe and effectual for the uſe of His Majeſty's ſubjects as a bridge, as if every thing were reſtored to what it was at firſt?

6thly, Whether, in virtue of the words "good and effectual repair," Mr. Errington may not in this repair omit every expenſe that is merely ornamental, in caſe he ſo chuſes?

7thly, As the riſk of the bridge's ſtanding after the repair, lies with Mr. Errington for a certain term, in which, if it ſhould fail, he will be obliged to repair *toties quoties*, whether in caſe he again employs Mr. Smeaton, and Mr. Smeaton will again engage in the concern, whoſe judgment, by the agreement, is made the *dernier reſort*, whether this will not bar all interference and controul of the magiſtrates as to the modes to be purſued of repair and re-erection of the particular parts that require it?

8thly,

8thly, Whether the certificate of the magiſtrates, and the acquieſcence of the whole body by paying Mr. Errington the laſt payment due on ſuch certificate, be not a full bar to the magiſtrates to any cavil that may be raiſed now, whether Mr. Errington fulfilled his contract in the erection, which, in reality, he did to the fulleſt extent, in the judgment of Mr. Smeaton, and which nobody thought of controverting till after the fatal diſaſter had happened?

9thly, Whether the time that has lapſed by the proceſs of a treaty of compoſition, which the magiſtrates have admitted from Mr. Errington, and to which they have never given a final anſwer till the Chriſtmas quarter ſeſſions held in January 1784, be not to be reckoned in part of the ſeven years from the time of the certificate, which was at the ſame time three years before?

10thly, Whether if Mr. Errington, aſſiſted by the judgment of Mr. Smeaton, repair the bridge ſo as to be in every reſpect as effectual for uſe, and as ſufficient in point of ſtability, as the bridge was before the accident, and is ſo maintained by him to the end of the term to which he is obligated, he will not then be legally diſcharged from the penalty of the obligation into which he entered?

I beg leave, before I conclude, to declare once more, that, though I never thought it a difficulty to reinſtate the bridge upon a principle of permanency equal to what it was at firſt, yet from the experience of this accident I do not know of any method at any expenſe within the bounds of Mr. Errington's obligation to reinſtate it, ſo that it ſhall, in my opinion, have the ſame proſpect of permanency that I thought it had before the accident; yet ſuch a principle of ſtability as it had before the accident may enable it to ſtand longer than the lifetime of any man in being, or it may be thrown down again the next year; for as it is out of my power to calculate the uttermoſt powers that Nature can collect, ſo it is out of my power to ſay what will abſolutely ſtand againſt every poſſible violence.

Before the accident I thought this bridge had this permanent kind of ſecurity; in this, the accident has convinced me that I was miſtaken, and that I may be ſo again: but this I do apprehend, that had there been but one ſingle hour more between the downfall of the ſnow and rain in the night and the flood's acquiring its greateſt violence by the middle of the next day, it would in that time have ſo filled the reaches of the river below the bridge, as to have moderated its rapidity in paſſing the bridge from 1000 to 900 feet per minute; ſo that the bridge would have been ſtanding at this inſtant, and all

all thofe concerned in its erection receiving the praife that the public was pleafed to attribute to them for fo noble an erection, inftead of the difgrace attending the being unfuccefsful generals.

I remain, Sir,

Your moft humble fervant,

J. SMEATON.

A DISSERTATION upon the peculiar Hardfhip of the Cafe of HENRY ERRINGTON, Efq. in regard to his Bond for the Maintenance of Hexham Bridge for Seven Years.

" *GIVE me my Bond*," fays Shylock; " *I will have my Bond.*" This, though an ancient legendary tale, has been feized upon by that immortal genius Shakefpear, and wrought up in a ftriking degree, to fhew to what manifeft injuftice human laws are capable of, in particular inftances, when carried to a rigorous execution in thofe cafes to which, as unforefeen, they never have been intended to be applied. Had the laws of Venice been rigidly carried into execution in the prefent cafe, they would have been looked upon with abhorrence by all fucceeding ages; but in the way it was determined, we cannot lefs admire the ingenuity of the pleader, in finding out a circumftance by which the keen edge of the law was taken off, and ftrict and equal natural juftice rendered to all the parties, than the renowned decifion of *Solomon* between the two harlots; or the celebrated decifion of *Sancho Pancha* between the cook and the defendant.

What, in this cafe, do the magiftrates of the county of Northumberland purfue Mr. Errington in an Englifh court of juftice to obtain? Why, to obtain the payment of 9000l. from a perfon who never received from them more than 5700l. Do the magiftrates then mean to make money of Mr. Errington for the benefit of the county's purfe, merely becaufe they have caugh thim upon the hip? No; their own honour, jointly as well as feverally, will not prompt them to avow this. No; they fay that they fue Mr. Errington for the penalty of the bond of 9000l. to force him to re-erect the bridge, and maintain it for feven years in the terms of the contract. But fuppofing Mr. Errington to pay the 9000l., will any man undertake to erect a bridge for that fum, to maintain it for feven years, giving a bond for the performance, of 9000l.? (It fhould be 11,000l. to be a ftrict parallel), without which

they will not ftand upon the ground Mr. Errington does, nor the county be any better affured of their having a bridge. Certainly no man will, unlefs he is mad, or in no degree inftructed by the leffon the late fatal experiment has taught. Why then, what is the refult, but that the magiftrates of Northumberland, taking advantage of a particular turn of the law of this kingdom, mean to force a fum out of the pocket of Mr. Errington that he never received, in order to put it into the county's purfe, to enable the county, by a further addition of their own, to lay out a fum of money upon a further and more extenfive experiment, far greater than Mr. Errington's contract was to receive.

" But," fays Shylock, " it was your bufinefs to have confidered the confequences before you entered upon the bond. You executed the bond with your *eyes open*, and you muft pay the penalty."

But did Mr. Errington enter into this bond with his *eyes open?* Why, no; he certainly did not. Were any other perfon *now* to enter into a fimilar bond, it may be faid, that he really and truly enters upon it with his eyes open; that is to fay, with the neceffary degree of information to give him fome idea of the extent of the difficulties and hazard that were likely to attend it. The late erection may be confidered as a proper experiment to prove the degree of rapidity and violence that the river Tyne is fubject to fo high up in its courfe as the parts oppofite to Hexham; but, previous to this, there was nothing to furnifh an adequate idea, much lefs a pofitive proof, of the degree of violence of which this river is at times, under certain circumftances, capable.

A bridge new built oppofite Hexham, at the upper or weftern end of the town, of a conftruction fomewhat fimilar, though (according to the doctrine of fome) more fecure, as having piles and ftrong platforms under all the piers, in the compafs of a fingle night, in the inundation that happened in Nov. 1771, was totally taken down and deftroyed, nothing remaining the next morning but the north abutment. This will naturally fuggeft great violence in the river, or great weaknefs in the conftruction of the bridge; but to which the cataftrophe was principally to be attributed, does not pofitively appear: for the bridge being apparently right at darkening, and totally demolifhed at break of day the next morning, nobody happened to be witnefs of its deftruction, or of the fall that the water had in paffing the bridge from the up ftream fide to the down ftream fide thereof. All that could be feen next morning (the water being then a good deal fubfided) was, that from the marks it had left it had been very uncommonly high, and that it had not

not only taken the ſouth abutment clean away but widened that ſide of the river by 60 or 70 feet; all which indicate marks of great rapidity and violence, but *what degree* of it by no means appears: for if the water had roſe to the ſame height, and had been ſtagnant like a mill pond or tide river at high water, no degree of height or depth of water ought to hurt a bridge that is expreſsly built not to take any damage from mere wet; nor did any thing appear by which a fall even of two feet could be inferred: its failure therefore muſt appear to be owing not ſo much to the weakneſs of the conſtructed matter of the bridge as to the weakneſs of the ſtratum whereon it was founded.

The height of the flood that occaſioned the demolition of the laſt bridge, was in the middle of the day; and the beginning and progreſs of its fall witneſſed by many perſons; and before any derangement had happened, it had been remarked what member of the bridge the water was even with on the up ſtream ſide, and what member from the down ſtream ſide, which from its known dimenſions, amounted to near upon five feet of difference of level; ſo that the water came down in this flood with ſo much rapidity and ſuddenneſs, that not being able to fill the reaches of the river and vallies below ſo faſt as it came down, it formed there a *breaſt* of the aſtoniſhing height or fall of near five feet perpendicular: and from a fall of leſs than five feet, that is, of four feet five inches, there neceſſarily reſults a rapidity of the torrent, amounting to one thouſand feet in a minute; a quantity of fall and rapidity, that *could it have been known* from the deſtruction of the former bridge, or even had there been found a fall of *half this quantity*, Mr. Smeaton can take upon him to ſay, it would have deterred him from encouraging Mr. Errington to have had any thing to do with undertaking the propoſed bridge: ſo that it may be fairly ſaid, that neither Mr. Errington, nor any of his adviſers, either had or could have that degree of information as to warrant its being ſaid, that Mr. Errington executed the bond with his *eyes open*: but any one now that enters upon a ſimilar obligation muſt enter into it with his eyes open; becauſe from the late fatal experiment, he will know this *capital and leading maxim*,—that by the ſudden melting of ſnow, accompanied with a violent downfall of rain, pouring from the ſteep ſides of thoſe hills extending to the very ſources of two large rivers that join a little above Hexham, there is a capability of the waters coming down with that ſudden violence, as that in the ſituation of the late bridge, the torrent is capable of forming a breaſt of near five feet, and conſequently, of acting with a certain rapidity of at leaſt a thouſand feet per minute; and knowing this for a certainty alſo, drawn from the ſame experience, that this velocity is capaple, not only of tearing up the bed of the river, but of removing all ſuch rough materials of ſtone as may be depoſited for the defence of the regularly conſtructed works.

Whoever

Whoever will therefore now undertake to build a permanent bridge, muſt be provided with ſuch a deſign as not only will be proof againſt all the violence and cauſes of derangement already aſcertained and deſcribed, but, as it cannot be known for a certainty that the violence already experienced is the uttermoſt that Nature is capable of, in this place, he ought to be ſtill more firmly fortified on that account, to reſiſt ſuch further violences as may poſſibly happen: all which, in Mr. Smeaton's judgment, cannot be expected to be done for a much larger ſum than the penalty of Mr. Errington's bond; much leſs for the ſum of money and value in materials, that Mr. Errington actually received.

Had Mr. Errington drawn the magiſtrates of Northumberland into the ſcheme and idea of building a bridge at Hexham, merely to ſerve his own purpoſes, and after a very conſiderable expenſe to the county, it had ended in the ill-fated cataſtrophe that has happened; had Mr. Errington had a view to make a profit of this buſineſs; had he been ſparing of any apparently neceſſary expenſe for the accompliſhment thereof; had he let it by the great, to be executed by under workmen, and thereby eaſed himſelf of the trouble and attention neceſſary to ſuch a work, and withal put a round ſum of money into his own pocket; had he employed incompetent artiſts to direct and ſuperintend the work, or adviſed with ſuch, as to the practicability and mode of accompliſhing it, who were not of eſtabliſhed reputation in the country for works of the kind;—in ſhort, had Mr. Errington practiſed or attempted to practiſe, any fraud in the conduct of this affair, or acted with any ſiniſter views, in any of theſe caſes it would have been natural for the magiſtrates, finding themſelves cheated, deluded, and diſappointed, to have purſued Mr. Errington with the rancour and vindictive ſpirit they are now doing: but if it ſhall appear that the very reverſe of all theſe things is the truth; if it ſhall appear that the magiſtrates had entertained this ſcheme and idea from the ſuggeſtions of the late worthy and univerſally eſteemed and reſpected Sir Walter Blackett, the upſhot of which, as reſpecting him, was the total demolition of the bridge, as already deſcribed, in 1771; if the diſappointment ariſing from this fatal cataſtrophe was ſo great to the magiſtrates, that, on Sir Walter Blackett's refuſal to be concerned with the bridge any further, chooſing rather to pay the penalty of a bond that he had entered into with the County, than further embark in ſo ill fated, in ſo apparently uncertain and hazardous an undertaking *: I ſay, if on this refuſal of Sir Walter, the magiſtrates ſtill remained ſo eager for a bridge that they actually began to erect another near the ſame place, and for this purpoſe engaged an eminent engineer to direct and

* Sir Walter Blackett entered into a bond, the penalty whereof was 3000l. the identical ſum that he received from the County, towards building a bridge at this place. The bridge certainly coſt a far larger ſum; but the voluntary ſubſcriptions of ſeveral gentlemen whoſe eſtates lay in that neighbourhood, made a part of the extra ſum expended, no part of which was refunded by Sir Walter.

ſuperintend

superintend the work †, with a resident surveyor of his own choice and recommendation ‡; and if after making some progress in the work, this same engineer gave it up as impracticable, on account of the insufficiency of the foundation; if the magistrates notwithstanding still remained unsatisfied, and eager to that degree as even to attempt to draw in the poor working masons of the country to take this great hazard upon them, (after a declared impracticability by an eminent engineer) to the probable ruin of themselves and families; I say, if, after all this ardour for a bridge on the part of the magistrates, Mr. Errington was the unhappy sacrifice delusively taken in by their offers §; then it may be fairly said, that the magistrates have drawn Mr. Errington into a scrape, and not Mr. Errington the magistrates; and that in taking the thorn out of their side he put it into his own; for which act they are now fully bent to punish his ill success by a rigorous exaction of a sum of money that he never received.

True it is that Mr. Errington had a view, he had a *motive* in this business; but if that motive was a laudable one, why punish his want of success with so much rigour? We do not read of any age where men undertook works for the public service, merely for the sake of having the trouble of performing them; mankind in every age had a *moving cause* of action. Did Sir Walter Blackett engage in building a bridge opposite Hexham without any other moving cause than the mere good of the public? Certainly not. Sir Walter Blackett had a very considerable estate opposite the upper or western part of the town of Hexham, and was lord of the manor of the whole. Had Sir Walter Blackett had no moving cause but the mere *public utility*, to fix the destination of the good he intended to mankind, he might have found many other places to promote the building of a bridge in England, and some in Northumberland; but it must be allowed, that the above circumstances

† Mr. John Wooler, who was then rebuilding the bridge of Newcastle, overthrown by the same flood, and which was afterwards finished by him.

‡ Mr. Jonathan Pickernell, from London; afterwards made Surveyor of the County Bridges of Northumberland, and recommended by some of the magistrates to Mr. Errington and Mr. Smeaton, to build Hexham Bridge under his direction.

§ Whoever was the least conversant with the public transactions of this county, in the years 1775 and 1776, will well remember an advertisement coming from the magistrates of this county, and appearing in all the three weekly papers of Newcastle, *importing* their readiness to treat with any person that would engage to build a bridge at Hexham, according to a design or plan for a *superstructure*, lodged for their inspection with the clerk of the peace. The offerer to be at liberty to pursue *his own plan or method* of constructing the *foundations* (under water), but to give security for the permanency thereof for seven years. This was the purport, as it occurs to memory; but the masons and working mechanical artificers were too wise to take the risque of such impending ruin: and the consequence was, that after continuing the said advertisement weekly for the greatest part, if not the whole of a year, without any adequate offer, it was Mr. Errington's ill fate to be seduced by those colours so hung out.

2

circumstances ought not to take from the merit of Sir Walter's fixing his efforts at Hexham, and building the bridge so as to land, on the north side, upon his own estate.

In like manner, Mr. Errington having an estate opposite to the town of Hexham, on the eastern or lower part of the town, being also desirous to have the bridge to land at the north end upon his estate, the benefit that was likely to accrue thereto was a sufficient inducement to him to engage in that very great scene of trouble and attention that must necessarily arise in the building of a bridge in such a situation, and of such a magnitude, without the least prospect of any profit, or other advantage by the building; on the contrary, it was Mr. Errington's professed declaration to Mr. Smeaton, when he applied to engage his advice, opinion, and assistance, that so far from meaning to be a gainer by the undertaking, he should not be disappointed if he were 2 or 300l. out of pocket; and which, it will be proved, actually turned out to be the case.

In regard to the competency of Mr. Smeaton, to form a judgment of and properly execute such undertaking, this may be separately discussed: but it will certainly exculpate Mr. Errington in having employed him, when it is recollected, that at *that time* Mr. Smeaton had had *no bridge fallen*, had been employed in the full scope of business in his profession no less than 25 years, and at that time had given proofs of his abilities by a constant success in executing the most difficult works, in almost every part of Great Britain, without *then* the failure of a *single subject*.

If therefore Mr. Errington acted the part of a wise, a prudent, an upright, and a disinterested man, willing to promote the public good, along with his own; if in a laudable attempt towards this end he has failed, from causes that could not in their *own nature* be *foreseen*; it must be allowed to be *hard*, nay *very hard* indeed, that Mr. Errington not only cannot be excused in his failure, but he must be actually positively *punished*. Does the law admit no remedy? The law-men say of *none*; nay it is not even in the power of the magistrates to remit any part or tittle of the *penalty of the bond!* so says the *written* law of England!

But what says *natural justice* in the case? that law which is written in the breast of every rational man, and is properly deemed the law of *equity* and of *good conscience*; does this agree in the same determination? No, it revolts from the idea, and says, that to exact the full penalty of the bond in the present case, would be the most shocking injustice to Mr. Errington. Is no one then in a legislative sense, in possession of the executive part of this law of equity, and good conscience? Yes, reason answers, every man in quality of a Bri-

a *Britiſh juryman* poſſeſſes it, and has the adminiſtration of it in his power; he alone can draw the line of right and wrong, in the *particular* caſe before him, where the written general law of the kingdom can (from the nature of the thing) draw none; and it is a wiſe proviſion of the general law, to leave the deciſion of particular caſes to the *breaſt* of a jury; where the law itſelf has not, nor can fix the limits of right with an adequate degree of preciſion. For this reaſon, a juryman's determination is *upon oath;* the purport of which oath is to the effect, that he will uſe his judgment according to his conſcience; for there is no need of an oath, if it is to be ſuppoſed that a juryman is previouſly and externally fixed to a point; that is, that he is to judge, without having the uſe of his judgment.

When a juryman has heard all parties and perſons who have any thing to ſay in the queſtion; he is aſked by the judge, whether he finds for the plaintiff or the defendant? that is to ſay, if the right is for the plaintiff or the defendant? if for the plaintiff, what are the damages? Now is it poſſible that any juryman can lay his hand upon his breaſt and ſay the plaintiffs are damaged to the amount of 9000l., when it is fully proved, that the value of every thing that the defendant received from the plaintiffs, incluſive of the road that ſtill remains, was but 6100l., and in this 6100l. they are damaged no more, than upon a fair eſtimate it would coſt to reinſtate the building as agreed for *; for the magiſtrates cannot be allowed to ſay, that to reinſtate the building as it was agreed for, will not now be likely to anſwer our end in point of permanency; he ſhall either build a *better bridge*, or *give us money* wherewith to do it; this certainly cannot now be admitted from the plaintiffs *in foro conſcientiæ;* becauſe it is the light drawn from the experiment made by Mr. Errington, that alone makes the magiſtrates now to ſee the neceſſity of building upon a more extenſive plan; and ſince it was they themſelves that practiſed the deluſion, in order to draw any unwary perſon they could into the ſcheme (which unfortunately for himſelf, happened to be Mr. Errington), they certainly ought not to be *gainers* by this deluſion. If Mr. Errington pays them back what upon a fair eſtimate it is likely to coſt, to reſtore it to what it was; even this puts the magiſtrates in a *better* ſituation, than they would have been, if by the combination of natural cauſes, this flood had been no more violent than common, and which this bridge had withſtood before; in which

* The contract was, to be paid 5700l. in money by inſtalments as the work advanced, for the bridge, and 400l. to Mr. Donkin for making a road, in the whole 6100l.; alſo Mr. Errington was to receive all ſuch materials of timber, ſtone and iron, as the magiſtrates themſelves had provided during their efforts to get a contract; — theſe materials were valued by the magiſtrates to Mr. Errington at 2000l., though in reality they never were of 1000l. value to him; and as the road ſtill remains, and there is much more value now upon the premiſes towards a bridge, than Mr. Errington received, the magiſtrates in receiving the preſent materials from Mr. Errington towards a bridge, will be gainers upon what he received from them.

caſe

caſe it would have now been left upſtanding; becauſe they are aware, in attempting to reinſtate it, that ſuch powers of reſiſtance are *now* required, of which before its downfall they could not poſſibly have formed any conception; which knowledge will be of moſt *important uſe* to any one who finds courage to become a future builder and guarantee for the upſtanding thereof.

Nay, ſuch is the utility of the knowledge gained by this experiment, that in the eye of reaſon, the whole charge thereof certainly ſhould not be ſolely upon Mr. Errington. The magiſtrates, if *nolens volens* they muſt have a bridge at Hexham, ſhould contribute to this experiment as well as he; and therefore only a moiety of the ſum eſtimated for reinſtating the building, ſhould be reimburſed by Mr. Errington, as his proper ſhare of an unfortunate adventure; and the other half ſhould be allowed by the magiſtrates for the experience gained: and then upon this fund of money and knowledge, and an adequate ſum in addition for its more extenſive conſtruction, they may with ſome degree of proſpect hope to poſſeſs a permanent bridge at the public expenſe, without forcing it out of a private man's pocket.

That juries do in other caſes exerciſe this kind of judgment, is manifeſt. I become bound in the penal ſum of 2000l., that *A.B.* ſhall duly fulfill the truſt repoſed in him by a certain company, deliver a true account, and all moneys, papers, and writings committed to his care, upon being thereto required. It happens that he abſconds, carries off every thing that he had in his charge, and 1000l. of the company's caſh. The company ſue me with an intent to recover 2000l. upon the bond; but though he has broken every article for which I became bound, yet unleſs the company can prove the intrinſic value of the books and writings, and that by the breach of his honeſty, they have in fact ſuffered a real pecuniary loſs of more than the real ſum of money deficient; will any jury puniſh me by the payment of 2000l. for the delinquency of another, when the whole of their intrinſic loſs is no more than 1000l.? ſurely they will not.

Again, in the common caſe of a bond for repayment of money borrowed; the common condition of the obligation is, that if the obligee pays a certain ſum (commonly one half of the penal ſum) upon a certain day with lawful intereſt for the ſame, *without fraud or further delay*, then the obligation to be null and void, otherwiſe to remain in full force and virtue. We will ſuppoſe the obligee fails in every article, wherein he has been bound; he neither pays the ſum nor the intereſt at the time; he makes many fraudulent promiſes of payment at a future day, merely to gain time till he can abſcond; and makes uſe of every ſhuffling pretence, at any rate to *delay* the payment: It may happen, and often does,

does, that for want of the money at the time, the obligor is prevented from fulfilling a purchafe that he has made; by which he would have got a profit equal to the fum, and in failure thereof may himfelf be fubject to an action; and after all this he is put to the neceffity of profecuting an action to recover his own; this is *very hard*, but will a jury punifh this obligee for his fraud, failure and neglect by finding in damages the whole penalty? No, they will calculate what his principal and intereft comes to; allow him that, with expenfes of fuit, and give damages accordingly. But here we are told, that this difpenfing power in the breaft of a jury, is limited in confequence of an *act of parliament*, exprefsly made for this purpofe, fo that let the penalty be what it will, the obligor can recover no more than the real pecuniary damage.

Very well; but does not the very making of fuch an act of parliament infer the judicial power of a jury, that fubfifted in their *breafts*, before the act was made? and therefore, where there is no act to fix the line of law, that it ftill refts in the breafts of a jury? the thing fpeaks for itfelf. Acts of parliament are not made to remedy an evil that has never exifted. It is not to be doubted, but that before this act, it was common for a defigning obligor to trump up a detail of the damages he had fuffered, by the money not being duly paid according to the obligation of the bond, in order to extort the whole penalty; and though this might fometimes be the cafe, that the obligor might fuffer by the neglect of the obligee, yet it doubtlefs would be pretended ten times for once, that it really was the cafe. It might alfo happen to fome juries not to have that accuracy of reafon and difcernment, but to fuppofe themfelves under an abfolute *obligation* to find the full penalty, though an adequate damage might not be fo clearly made out, conceiving the penalty to be the proper punifhment for non-performance. In order fully to fettle thefe matters upon the beft general grounds, an act has been found neceffary to reftrain the jury's difcretion from proceeding beyond a certain line; and nothing can be a ftronger proof of the full extent of a juryman's power of difcretion, than this act of parliament, to reftrain it in this particular cafe. It is not therefore to be doubted, but that every jury-man who is fully fenfible of what is due to his own character, and the full extent of Mr. Errington's cafe, will perceive, that as he has the power, he undoubtedly will have the will, to draw the mercilefs teeth of the lion, and not fuffer them to fix unreafonably deep in the flefh of an innocent man; and this even at the expenfe of his own oath in giving exaggerated damages, where mitigated damages only are due.

BERWICK BRIDGE.

The REPORT of JOHN SMEATON, Engineer, upon the State of Berwick Bridge, from a View thereof, the middle of September 1771.

Notes taken on View.

THE key from the upper birth to the bridge, appears to be in a ruinous condition.

N.B. The north weft abutment wall of the bridge fwayed out, and overleaning, it feems proper to be fupported by a buttrefs.

The fplay wall up ftream wants pointing.

The fecond courfe of arch ftones in the firft arch from Berwick, is decayed in the weft face near the crown of the arch; the ftones that are perifhed fhould be fhifted.

The Piers to the fourth inclufive being in hand to be pointed and repaired, and in great part done, it is needlefs to fay any thing as to the reparation thereof.

Fifth Pier—Some ftones deficient, and the lower point of the ftarlings frame beginning to decay, thefe matters fhould be attended to.

Seventh Pier—Several ftones out of the fides of the pier, and alfo fome ftones out of the old ftarling jetty or frame, as well as the new, which laft is fettled and confiderably deranged.

Ninth Pier—The north fide of the ftarling wants planking, and the upper peach is in bad condition; it may be rebuilt, or with repair, may be expected to laft a few years longer.

Tenth Pier—The fheeting on both the north and fouth fide of the ftarling wants repairing, as alfo the peak.

Eleventh

Eleventh Pier—The down ſtream point of the ſtarling is decayed, the north ſide wants planking half round, and the ſouth ſide wants the looſe ſtones righting up againſt it.

Twelfth Pier—The down ſtream point of the ſtarling is out of repair, the ſides want planking all round, and the ſouth ſide more particularly wants repairing.

Thirteenth Pier—The ſtarling wants planking all round, and the looſe ſtones righting up in the paſſages, and laying regularly againſt the ſides of the ſtarling; the peak of the pier has ſettled, but with repair may probably laſt a few years longer.

Fourteenth Pier—The ſtarling wants planking on the north ſide, and its down ſtream point is deficient. In the face of this arch and the next ſome ſtones are wanted on the weſt ſide, but as they are found in the ſoffite underneath, they are not in imminent danger, and by ſhifting the decayed ſtones may be properly repaired.

Several lengths of the parapet of the bridge are overleaning, ſome of the worſt places ſhould be taken down and rebuilt, and the terminating pillars of the abutment parapets on the ſouth end of the bridge being in a ſtate of diſrepair, ſhould be made up again to prevent further derangements to the parapets.

N. B. Reference has alſo been had to the report of Meſſrs. Wilſon, Dods, Buglaſs, and Steel, dated 21ſt June 1771.

This bridge having been built ſeveral centuries, has felt the effects of time, and beſides the decay of the ſtones in ſome particular places, the mortar is in general periſhed from the joints, as commonly happens to buildings of the ſame age, and alike expoſed. Nothing would ſo much contribute to an appearance of good repair as to have the joints new pointed, and could this be done in an effectual manner it would in reality contribute to its duration; but the imperfect union of new mortar with old, and with ſtones in a ſtate of waſte, is ſuch, that the froſts and rains in the courſe of a very few years generally undo whatever of this kind is done, even when executed with great care: however, it being very ſatisfactory to the public eye to ſee matters of this kind look well, I cannot but recommend it to thoſe who have the management of the repairs of the bridge, to do as much of this as they can, without neglecting what is really eſſential.

This bridge, like moſt of the ſame age built in tide rivers, has been founded on piles ſawn off above low water, for the defence of which from the injuries of the weather, and alſo to ſecure the ground round each aſſemblage of piles for the forming of a pier, each aſſemblage has been ſurrounded with another work called a ſtarling or frame, which is terminated

terminated ſo much above low water as to cover the wood work immediately under the pier; and as theſe ſtarlings are conſidered only as a work of defence, whoſe ſurface is in general wood, they muſt of courſe be ſubject to decay from the injuries of the weather and the wear of the water; the piles in the ſides of the ſtarlings in time therefore want renewing, and when that is the caſe, as they can eaſier be done by ſurrounding the former work with a freſh row of piles than drawing out the ſtumps of the old ones, it happens that the *eaſieſt way* is often taken: but as this increaſes the bulk of the ſtarlings, and of courſe contracts the water ways, the rapidity of the flood tends in a greater degree to ſap and deſtroy thoſe outworks, and then recourſe is had to ſtones to ſecure the ſtarlings, and the intermediate bed of the river, which ſtill increaſing the obſtruction, form altogether a kind of dam, over which the water falling pools a great hole below the bridge, which often threatens the deſtruction of the whole. For theſe reaſons I cannot commend the firſt laying of the ſtones round the ſtarlings, and leſs the extending the ſtarlings themſelves ſo far from the ſides of the piers as to require it; but when done, as one evil is frequently applied to cure another, perhaps it may not be ſo perfectly ſafe juſt now to take away the ſurrounding ſtones already placed; but it is very material that the repair of the ſtarlings ſhould be duly attended to, as the ſafety of the whole bridge depends upon them; and when any repair is made to do it in ſuch a manner as not to contract the preſent water way, but whenever it is poſſible by contracting the ſtarlings ſideways to increaſe it, and whenever the down ſtream points of the ſtarlings become dangerous, by the pooling of the ground below the bridge, and taking it too much away from the tail of the ſtarlings, it will be the beſt and cheapeſt way to ſecure the bottom by throwing in rough rubble ſtones from the quarry; and though this may in ſome ſenſe be conſidered as a contraction, yet being chiefly in the eddy of the pier, will not have the effect of ſuch, and is to be applied only in ſuch a degree as the matter there has become defective in quantity: it is poſſible that after ſuch application ſome of theſe ſtones, by being laid too ſteep againſt the ſtarlings, may be carried down by the ſucceeding floods; but as this will only happen by their being too ſteep, by ſliding down they enlarge their baſe, and by filling up the place from whence they have ſlided, they will in the end remain immoveable like a rock.

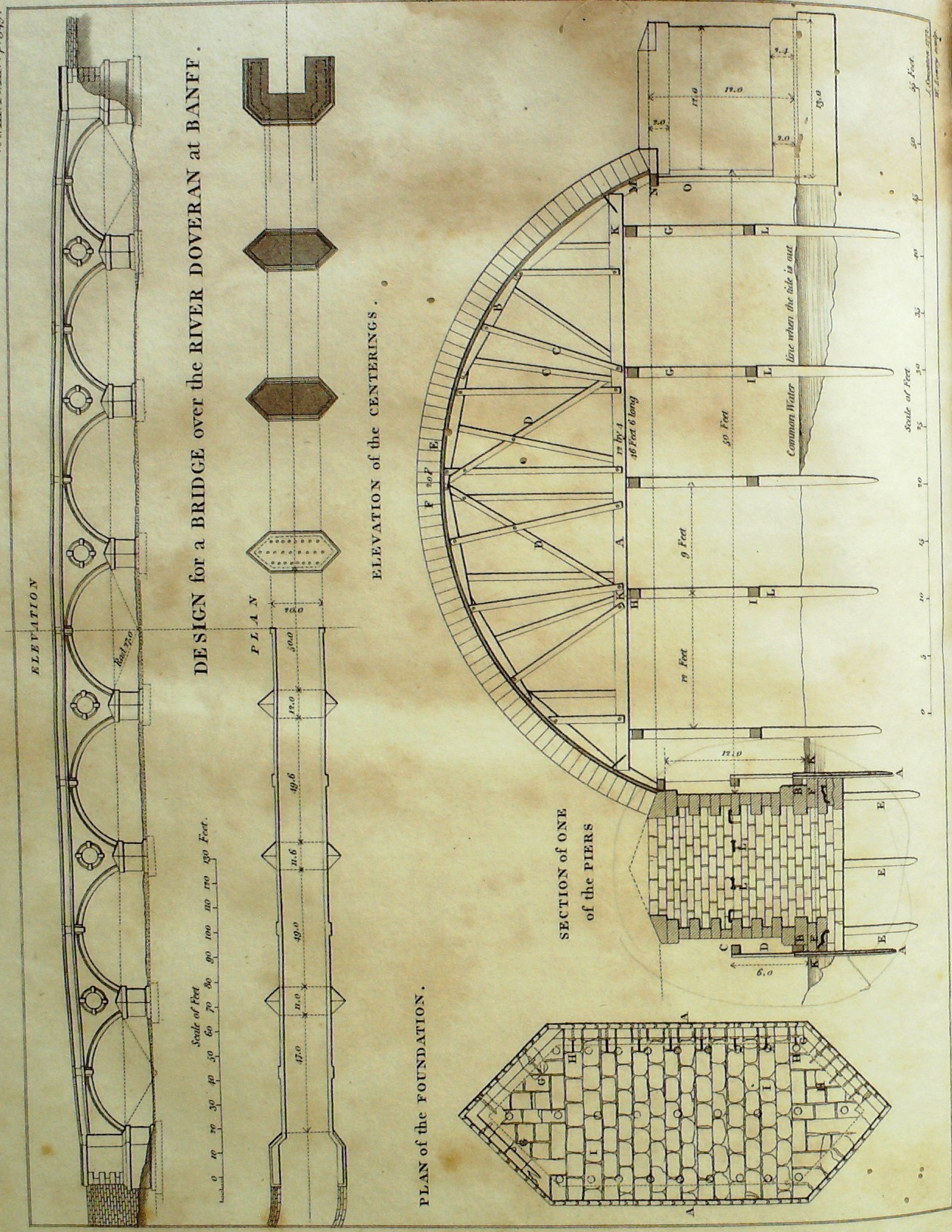
By attempting to put the ſtones into a frame at the tail of the ſeventh ſtarling for the ſecurity of the down ſtream part of that ſtarling, in the caſe above mentioned, and for want of ſomething to keep the ground from being carried away round this new jetty, it has ſettled and the ſtones therein have become deranged; but if the wood work could be drawn out, and the ſtones ſuffered to form their own ſlope, and freſh ſtones

ſtones added where they may be defeƈtive, I apprehend this ſtarling would thus be effeƈtually ſecured.

In regard to the up ſtream peaks of the piers which have ſettled and cracked, as the arches do not immediately depend upon them, the building thereof is a matter leſs preſſing, eſpecially when it is conſidered how difficult it is to unite the new work with the old, ſo as to prevent a ſeparation even after they are rebuilt.

J. SMEATON.

Auſthorpe,
16th *June* 1772.



BANFF BRIDGE.

(See Plate 14.)

ESTIMATE for building a Bridge over the River Doveran near Banff, to be of 410 Feet between the Abutments, 20 Feet wide over all, and to consist of Seven Arches; the Aisler of the Piers, Arches, and Facings of Freestone, and the Core of the Piers, Spandrell Walls, and Parapets of Rubble.

	£.	s.	d.	£.	s.	d.
PREPARATION for founding the PIERS.						
To timber in coffer dams for the six piers and two abutments, exclusive of what is to remain connected therewith, 1278 cube feet at 3*s.* 6*d.*	223	13	0			
To iron work to do. 12 cwt. 2 quarters, at 5*d.* per lb. - -	29	3	4			
To pumps, piling machines, and utensils - - - -	100	0	0			
				352	16	4
The PIERS and ABUTMENTS to the Spring of the ARCHES.						
To excavations and pumping for eight foundations at 15*l.* - -				120	0	0
To timber in plank piles, bearing piles, ribbands, &c., for the eight foundations, 2788 cube feet, at 4*s.* - - - -	557	12	0			
To iron work for the six piers and two abutments, 22 cwt., at 5*d.* per lb. - - - - - - - -	51	6	8			
To lead 10 cwt., at 2*d.* per lb. - - - - - -	9	6	8			
				618	5	4
To aisler in 14568 cube feet, at 6*d.* - - - -	364	4	0			
To rubble work in do. 82 roods Scots, at 4*l.* 16*s.* - - -	393	12	0			
To 2*d.* per foot extra upon 4024 cube feet of rubble blocks to serve in the inside for the bottom, tie and bond courses as aisler - -	33	10	8			
To 50 tons of Pozzelana, at 3*l.* per ton, ground and sifted ready for use	150	0	0			
				941	6	8
To 450 cube yards of rubble to be deposited round the piers for securing the bottom, at 1*s.* - - - - - -				22	10	0
Total of piers and abutments,				2054	18	4

The

The SUPERSTRUCTURE.

	£	s.	d.	£	s.	d.
To centering for the arches which contain at a medium 1220 feet superficial in the soffite, and for seven arches 8540 feet, at 10*d*. -				355	16	8
To aisler in the arches, which at two feet thick contain 17080 cube feet, at 6*d*. - - - - - -	427	0	0			
To aisler in the capings and facings 4792 feet at 6*d*. - -	119	16	0			
To rubble work in the whole superstructure, 104 roods, at 4*l*. 16*s*. including scaffolding - - - - - -	499	4	0			
To extra work 16787 feet, face measure of rubble walling in the spandrells, abutment walls, and parapets, 1*d*. - - -	69	18	11			
To cramps and lead for the caping - - - -	15	8	0			
To filling the spandrells and abutments with quarry scraps and levelling the whole length of the bridge with gravel, 2417 cube yards, at 6*d*. -	60	8	6			
				1191	15	5
Total of the superstructure,				1547	12	1

The TERMINATING SLOPES by way of Access to the Bridge.

	£	s.	d.	£	s.	d.
To dry rubble building wharf walls for confining the forced earth at the north-west end of the bridge, containing 25½ roods, at 3*l*. per rood -	76	10	0			
To rubble parapets in mortar to do. at 4*l*. 16*s*. - - - -	21	12	0			
To extra work on 400 feet running of rubble caping and base of the parapets, at 3*d*. - - - - - -	5	0	0			
To gravel, &c. for levelling the south east end of the bridge, and for forming the slope on the north west end, so as not to be steeper than one in twelve, containing 3400 cube yards, at 6*d*. - -	85	0	0			
				188	2	0

ABSTRACT.

	£	s.	d.	£	s.	d.
The piers and abutments - - - - -	2054	18	4			
The superstructure - - - - -	1547	12	1			
The terminating slopes - - - - -	188	2	0			
Neat estimate				3790	12	5
Contingencies on the above at 10 per cent. - - - -				379	1	3
The above being supposed to be performed by those who are expert in this kind of works, we may add for surveyors and profit of undertakers or inexperience of workmen 10 per cent. more - -				379	1	3
Total,				4548	14	11

N. B.

N. B. The above estimate is on supposition that every thing is to be provided, and nothing to remain; but a considerable quantity of old materials of the late bridge has been preserved and deposited near the place; I suppose to the amount of 200*l*.; and the timber of the centers and coffer dams will remain at last to be disposed of.

A quarry very near the bridge, which affords excellent rubble, greatly contributes to the smallness of expense for so large a building.

J. SMEATON.

Austhorpe,
19th *February* 1772.

EXPLANATION of the manner of laying the Foundations for the Bridge of Banff.

A—Plank piles encasing the pier and serving as a coffer dam for laying the foundation.

B—String piece first laid for regulating and connecting the plank piles above the common surface of the water.

C—Another string piece for connecting the tops of

D—Planking for keeping out the tide water.

The inside is then to be excavated to the depth required.

E—Bearing piles to be increased or diminished in number, length, or size, according as the ground is found more or less firm: those drawn will do for a middling gravel.

F—A ribband or string piece which is to be adapted to the inside of the piles, and with screwed bolts, (whose threads lay hold of the planks on the outside, but go freely through the ribband) to be fixed to every other plank, and as many of them as are here represented like.

G—Are

G—Are bolts with flat ſhoulders, and an eye in the head, by which they are tied with cramps to

H—Blocks of rough ſtone holding the cramps for tying in the outſide caſing firmly to the pier.

I—Flat rubble blocks for the ground courſe to tie the baſe together.

When the pier is raiſed above low water mark, then the upper part of the coffer dam with its ſtring piece, croſs beams, &c., are to be removed, and made to ſerve for another pier, the plank piles are to be cut off with chizzels at the dotted line K, five or ſix inches under water, and then the ſtring piece B, comes away and ſerves for the next pier.

The outſide muſt be guarded with rubble round the caſing.

N. B. By way of eaſing the driving of the plank piles, the ground ſhould be excavated ſomewhat wider than the pier, and as deep as the water will permit.

The plank piles (which are four inches thick) will be beſt made of beach, which can be had in planks of proper dimenſions from Suſſex.

J. SMEATON.

Auſthorpe,
19th *February* 1772.

EXPLANATION of the Center for the Bridge of Banff.

THIS deſign ſhows how it will ſtand under the middle arch of 50 feet ſpan.

A—One of the tie beams for framing one of ſeven ſimilar ribs.

B—One of the curbed fellies, there being ſix in each rib.

C. C—

CC—Struts or props of Scots firs about ſix inches diameter in the middle, and of their natural taper.

DD—Two braces in each rib for throwing part of the weight of the middle upon the two adjacent ſupports.

E—Shews the ends of two-inch planks for covering the center.

F—The vauſoirs or penſtones upon the centers two feet in height.

GG—Pillars or props of Scots firs of their natural taper, ten inches diameter in the middle: as there are ſhewn five under each rib, they will be ſeven deep, and each row of ſeven framed into head and ſell pieces, whoſe ends are ſhewn at

HI—Ten inches ſquare, and 20 feet long.

KK—Denote ſhort blocks of about five inches in height laid perpendicularly over each of the pillars above mentioned, ſo as to level up the tie beams to their proper height, which blocks are ſplit away from under the tie beams on ſtriking the centers.

The pillars G G are of ſuch a height that the frames H G I ſtanding upon the ground will ſupport the center when the two arches next the town are built (the length of the tie beam A being adapted to the ſpan of the ſmalleſt arches), in which caſe large flat ſtones well bedded upon the gravel, one correſpondent to each pillar G, will ſufficiently ſupport the ſell pieces I; but as the arches will riſe higher, and eſpecially thoſe which are over the channel of the river at low water will be more ſafely ſupported by

LL—Piles of Scots fir about 10 inches in the middle, driven into the gravel five or ſix feet more or leſs, till they make a conſiderable reſiſtance to the ram; they are to be driven in rows as nearly correſpondent to the preſent places of the pillars G as may be, and then their heads levelled down ſo as to ſuffer each ſell piece I to lay true upon each row of ſeven piles.

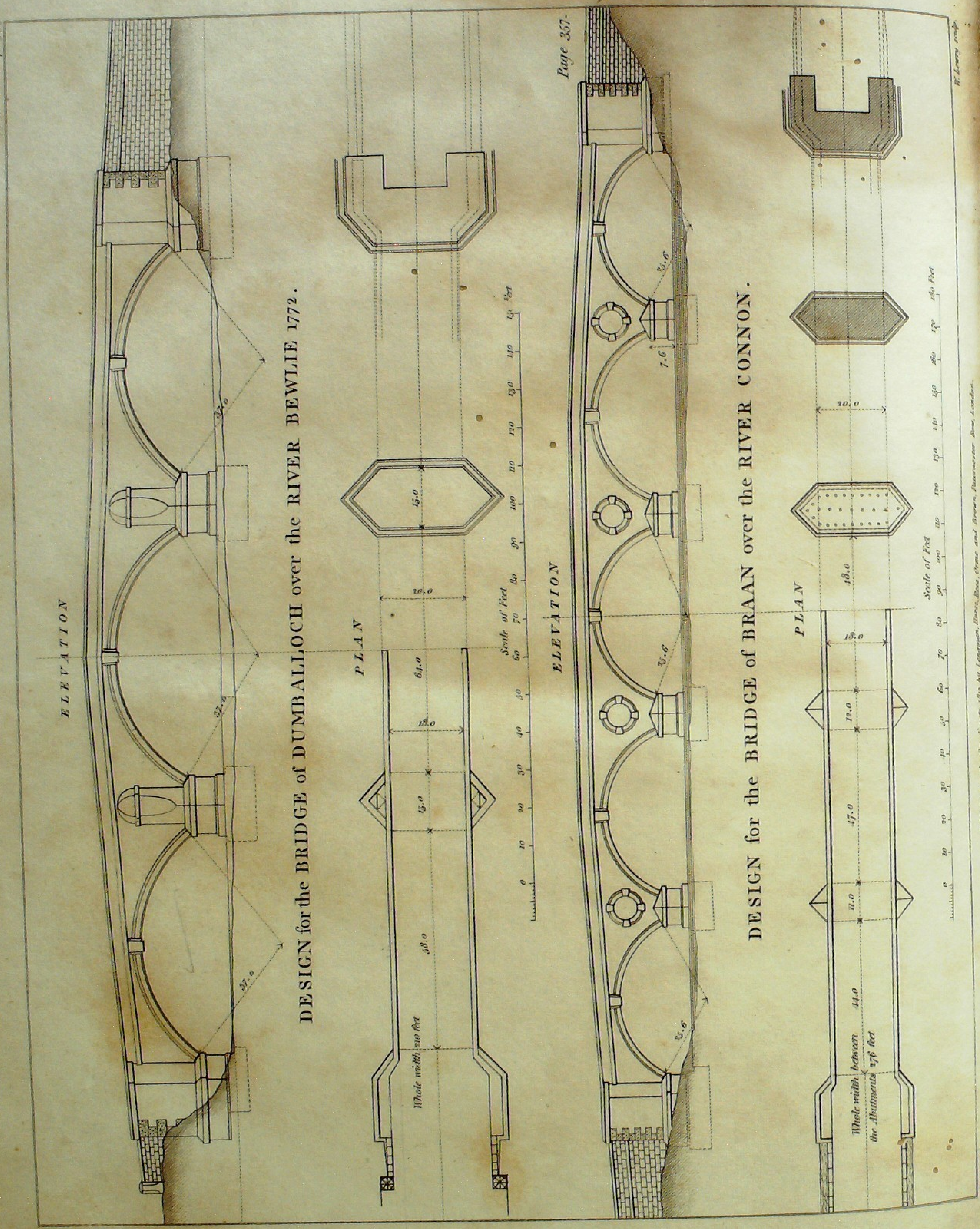
M—Curbed pieces anſwerable to each rib, put in ſo as to make out the center from the ſmalleſt to the greateſt arches; theſe reſt upon a plate piece whoſe end is repreſented at N, which are each of them ſupported by ſeven ſtanchions or props O, ſtanding upon

upon the loweſt offsett of the baſe of the piers, which may be of Scots fir five or ſix inches diameter in the middle.

To prevent confuſion, the ſtays that will be neceſſary to keep the work in place while putting together, I have omitted, as theſe will be obvious to every carpenter, but it is to be noted that every thing of this kind below the tye beams muſt be ſtruck away after the center is got together to prevent reſiſtance to ſpeats, in caſe theſe ſhould happen while the center is up.

J. SMEATON.

Auſthorpe,
31ſt *December* 1772.



DUMBALLOCH BRIDGE.

(See Plate 15.)

ESTIMATE for building a Bridge over the River Bewlie at Dumballoch, being 210 Feet between the Abutments, 20 Feet wide over all, and to consist of Three Arches to be built with Freestone.

PREPARATION for founding the PIERS.	£. s. d.	£. s. d.
To timber for coffer dams for two piers and two abutments (exclusive of what is to remain connected therewith), 783 cube feet, at 3s. 6d.	137 0 6	
To iron work for do. 7 3, at 5d. per lb. - -	18 1 8	
To pumps, piling machines, and utensils - -	120 0 0	
Total of the Preparations		275 2 2
The PIERS and ABUTMENTS to the Spring of the ARCHES.		
To excavations and pumping for the four foundations, at 20l. each -		80 0 0
To timber in plank piles, bearing piles, ribband, &c. for the four foundations, 2568 cube feet, at 4s. - -	513 12 0	
To iron work for two piers and two abutments, 12 cwt. 3 qrs., at 3d. per lb. - - -	29 15 0	
To lead, 6 cwt., at 2d. per lb. - -	5 12 0	548 19 0
To aisler in do. 12,304 feet (the leading being supposed not to exceed one mile) at 6d. - - -	307 12 0	
To rubble work in do. 64 roods Scots, at 5l. 10s. -	352 0 0	
To 2d. per foot extra upon 3600 cube feet of rubble blocks, to serve in the inside, for the bottom, top, and bond courses -	30 0 0	
To 35 tons of Pozzelana, ground and sifted ready for use, at 3l. 3s. -	110 5 0	
To 1432 cube yards of rubble, to be deposited round the piers for securing the bottom, at 1s. 6d. - -	107 8 0	907 5 0
Total of the Foundations		1811 6 2
The SUPERSTRUCTURE.		
To centering for the arches, which contain in the whole 4200 feet of soffite, at 1s. - - -		210 0 0
To aisler in the arches, which at 2 4 thick contain 9800 cube feet, at 6d. - -	245 0 0	
To aisler in the capings and facings, 2650 feet, at 6d. -	66 5 0	
Carried forward £		

	£. s. d.	£. s. d.
Brought forward		
To rubble work in the whole superstructure 71 roods, at 5*l.* 10*s.*	390 10 0	
To extra work upon the face of the spandrells, abutments, walls, and parapets, 9606 feet, at 3*d.*	120 1 6	
To lead and iron for cramping the caping	8 8 0	
Fitting the spandrells and abutments with quarry scraps, and levelling the whole with gravel, containing 1921 yards, at 1*s.*	96 1 0	926 5 6
Total of the superstructure		1136 5 6

The TERMINATING SLOPE at the South End of the Bridge, and Access on the North.

To dry rubble building in the wharf walls for confining the forced earth at the south end, containing 13½ roods, at 3*l.* 10*s.*	47 5 0	
To rubble parapet in mortar 1½ roods, at 5*l.* 10*s.*	8 5 0	
To extra work on 270 feet running of caping and base, at 3*d.*	3 7 6	
To 1500 cube yards of gravel for levelling the north end, and forming the slope on the south end so as not to be steeper than 1 in 12, at 6*d.* per yard	37 10 0	96 7 6

ABSTRACT.

The pier and abutments	1811 6 2
The superstructure	1136 5 6
The terminating slopes	96 7 6
Neat estimate	3043 19 2
Contingencies on the above, at 10 per cent	304 7 10
The above being supposed to be performed by those who are expert in this kind of works, we may add, for surveyors and profit of undertakers, or inexperience of workmen, 10 per cent. more	304 7 10
Total	3652 14 10

N. B. The above estimate supposes that rubble stone can be procured at 1*s.* 6*d.* per rood of wall laid down in place, and lime at 10*d.* per boll: if those materials cannot be procured at those prices, allowance must be made in the estimate upon them for the difference.

J. SMEATON.

Austhorpe,
19th *Feb.* 1772.

N.B. The foundations for this bridge are to be laid in the same manner as for Banff bridge.

BRAAN BRIDGE.

(See Plate 15.)

ESTIMATE for building a Bridge over the River Conon at the Boat of Braan, to be 276 Feet between the Abutments, 20 Feet wide over all, and to consist of five Arches; the Aisler of the Piers, Arches, and Facings to be of Freestone, and the Core of the Piers, Spandrell Walls, and Parapets of Rubble.

PREPARATION for founding the PIERS.	£. s. d.	£. s. d.
To timber in coffer dams for the four piers and two abutments, exclusive of what is to remain connected therewith, 340 cube feet, at 3*s.* 6*d.*	59 10 0	
To iron-work to do., 3 cwt. 2 qrs., at 5*d.* per lb.	8 3 4	
To pumps, piling machines, and utensils	120 0 0	187 13 4

The PIERS and ABUTMENTS to the Spring of the ARCHES.

To excavations and pumping for six foundations, at 20*l.* each		120 0 0
To timber in plank piling, bearing piles, ribbands, &c. for the foundations, 3162 cube feet, at 4*s.*	632 8 0	
To iron work for the four piers and two abutments, 16 cwt. 2 qrs., at 5*d.* per lb.	38 10 0	
To lead, 7 cwt. 2 qrs., at 2*d.* per lb.	7 0 0	677 18 0
To aisler in do. 15,120 cube feet (the leading being supposed not to exceed one mile), at 6*d.*	378 0 0	
To rubble work in do., 65 roods, at 5*l.* 10*s.*	357 10 0	
To 2*d.* per foot extra upon 4602 cube feet of rubble blocks to serve in the inside, for the bottom, tie, and bond courses, as aisler	38 7 0	
To 40 tons of Pozzelana, at 3*l.* 3*s.* per ton, ground and sifted ready for use	126 0 0	
To 1152 cube yards of rubble, to be deposited round the piers for securing the bottom, at 1*s.* 6*d.*	86 8 0	986 5 0
Total to the piers and abutments		1971 16 4

The SUPERSTRUCTURE.

To centering for the arches, which contain 5780 superficial in the soffite, at 8*d.*		192 13 4
To aisler in the arches, which at two feet thick contain 11,560 cube feet, at 6*d.*	289 0 0	
Carried forward £		

	£.	s.	d.	£.	s.	d.
Brought forward						
To rubble work in the whole fuperftructure 71 roods, at 5*l.* 10*s.* -	390	10	0			
To extra work upon the face of the fpandrells, abutments, walls, and parapets, 9606 feet, at 3*d.* - -	120	1	6			
To lead and iron for cramping the caping - -	8	8	0			
Fitting the fpandrells and abutments with quarry fcraps, and levelling the whole with gravel, containing 1921 yards, at 1*s.* -	96	1	0			
				926	5	6
Total of the fuperftructure				1136	5	6

The TERMINATING SLOPE at the South End of the Bridge, and Accefs on the North.

	£.	s.	d.	£.	s.	d.
To dry rubble building in the wharf walls for confining the forced earth at the fouth end, containing $13\frac{1}{2}$ roods, at 3*l.* 10*s.* -	47	5	0			
To rubble parapet in mortar $1\frac{1}{2}$ roods, at 5*l.* 10*s.* -	8	5	0			
To extra work on 270 feet running of caping and bafe, at 3*d.* -	3	7	6			
To 1500 cube yards of gravel for levelling the north end, and forming the flope on the fouth end fo as not to be fteeper than 1 in 12, at 6*d.* per yard - - -	37	10	0			
				96	7	6

ABSTRACT.

	£.	s.	d.
The pier and abutments - -	1811	6	2
The fuperftructure - - -	1136	5	6
The terminating flopes - -	96	7	6
Neat eftimate	3043	19	2
Contingencies on the above, at 10 per cent - -	304	7	10
The above being fuppofed to be performed by thofe who are expert in this kind of works, we may add, for furveyors and profit of undertakers, or inexperience of workmen, 10 per cent. more -	304	7	10
Total	3652	14	10

N. B. The above eftimate fuppofes that rubble ftone can be procured at 1*s.* 6*d.* per rood of wall laid down in place, and lime at 10*d.* per boll: if thofe materials cannot be procured at thofe prices, allowance muft be made in the eftimate upon them for the difference.

J. SMEATON.

Aufthorpe,
19th *Feb.* 1772.

N. B. The foundations for this bridge are to be laid in the fame manner as for Banff bridge.

BRAAN BRIDGE.

(See Plate 15.)

ESTIMATE for building a Bridge over the River Conon at the Boat of Braan, to be 276 Feet between the Abutments, 20 Feet wide over all, and to confift of five Arches; the Aifler of the Piers, Arches, and Facings to be of Freeftone, and the Core of the Piers, Spandrell Walls, and Parapets of Rubble.

PREPARATION for founding the PIERS.

	£.	s.	d.	£.	s.	d.
To timber in coffer dams for the four piers and two abutments, exclufive of what is to remain connected therewith, 340 cube feet, at 3*s.* 6*d.*	59	10	0			
To iron-work to do. 3 cwt. 2 qrs., at 5*d.* per lb. -	8	3	4			
To pumps, piling machines, and utenfils - -	120	0	0			
				187	13	4

The PIERS and ABUTMENTS to the Spring of the ARCHES.

	£.	s.	d.	£.	s.	d.
To excavations and pumping for fix foundations, at 20*l.* each -				120	0	0
To timber in plank piling, bearing piles, ribbands, &c. for the foundations, 3162 cube feet, at 4*s.* - - -	632	8	0			
To iron work for the four piers and two abutments, 16 cwt. 2 qrs., at 5*d.* per lb. - - - -	38	10	0			
To lead, 7 cwt. 2 qrs., at 2*d.* per lb. - -	7	0	0			
				677	18	0
To aifler in do. 15,120 cube feet (the leading being fuppofed not to exceed one mile), at 6*d.* - - -	378	0	0			
To rubble work in do., 65 roods, at 5*l.* 10*s.* - -	357	10	0			
To 2*d.* per foot extra upon 4602 cube feet of rubble blocks to ferve in the infide, for the bottom, tie, and bond courfes, as aifler -	38	7	0			
To 40 tons of Pozzelana, at 3*l.* 3*s.* per ton, ground and fifted ready for ufe - -	126	0	0			
To 1152 cube yards of rubble, to be depofited round the piers for fecuring the bottom, at 1*s.* 6*d.* - - -	86	8	0			
				986	5	0
Total to the piers and abutments				1971	16	4

The SUPERSTRUCTURE.

	£.	s.	d.	£.	s.	d.
To centering for the arches, which contain 5780 fuperficial in the foffite, at 8*d.* - - -				192	13	4
To aifler in the arches, which at two feet thick contain 11,560 cube feet, at 6*d.* - - -	289	0	0			
Carried forward £						

	£. s. d.	£. s. d.
Brought forward		
To aiſler in the capings and facings, 3060 feet, at *6d.* -	76 10 0	
To rubble work in the whole ſuperſtructure, 92 roods, at *5l. 10s.*, including ſcaffolding - - -	506 0 0	
To extra work upon 11,664 feet, face meaſure, of rubble walling in the ſpandrells and abutments, walls and parapets, at *3d.* -	145 16 0	
To cramps and lead for the caping - -	11 4 0	
To filling the ſpandrells and abutments with quarry ſcraps, and levelling the whole length of the bridge with gravel, 2384 yards, at *1s.* -	119 4 0	
		1147 14 0
Total of the ſuperſtructure		1340 7 4

The TERMINATING SLOPES, by way of Acceſs to the Bridge.

	£. s. d.	£. s. d.
To dry rubble building in wharf walls for confining the forced earth at the ends of the bridge, containing 14 roods, at *3l. 10s.* -	49 0 0	
To rubble parapets in mortar, to do. 2¾ roods, at *5l. 10s.* -	15 2 6	
To extra work on 384 feet running of rubble caping and baſe of the parapets, at *3d.* - - -	4 16 2	
To gravel, &c. for making the acceſs to the bridge, and for forming the ſlopes ſo as not to be ſteeper than 1 in 12, viz. 2048 yards, at *6d.* - - -	51 4 0	
		120 2 6

ABSTRACT.

	£. s. d.
The piers and abutments - -	1971 16 4
The ſuperſtructure - -	1340 7 4
The terminating ſlopes - -	120 2 6
Neat eſtimate	3432 6 2
Contingencies on the above, at 10 per cent. - -	343 4 7
The above being ſuppoſed to be performed by thoſe who are expert in this kind of works, we may add, for ſurveyors and profit of undertakers, or inexperience of workmen, 10 per cent. more -	343 4 7
Total	4118 15 4

N. B. The above eſtimate ſuppoſes that rubble ſtone can be procured at *1s. 6d.* per rood of wall laid down in place, and lime at *10d.* per boll: if thoſe materials cannot be procured at thoſe prices, allowance muſt be made in the eſtimate for them upon the difference.

J. SMEATON.

Auſthorpe,
19th *Feb.* 1772.

N. B. The foundations for this bridge are to be laid in the ſame manner as Banff bridge.

ALTGRAN BRIDGE.

ESTIMATE for building a Bridge over the River Altgran, near above the preſent Wood Bridge, to conſiſt of One Arch of 44 Feet Span.

	£. s. d.
To excavation for the abutments and laving the water for laying the foundations	5 0 0
To aiſler in the abutments to the ſpring of the arch, 392 feet, at *6d.* -	9 16 0
To do. in the arch, 1800 feet, at *6d.* - - -	45 0 0
To do. in the facings, 302 feet, at *6d.* - - -	7 11 0
Rubble work in the whole, 11 roods, at *4l.* - - -	44 0 0
Centering for the arch, ſuppoſed to be brought from the bridge at Braan -	15 0 0
Filling the ſpandrells and levelling the bridge with gravel - -	3 7 6
	129 14 6
To 5 loads of dry rubble walling to wharf up the ſlopes -	12 10 0
To 548 yards of earth for forming the ſlopes - - -	6 17 0
Total	£.149 1 6

N. B. It is probable the work may be undertaken for leſs money, but the quantities may nearly be depended upon.

The above eſtimate ſuppoſes the rubble ſtone can be procured at *1s. 6d.* per rood of wall laid down in place, and lime at *10d.* per boll: if thoſe materials cannot be procured at thoſe prices, allowance muſt be made in the eſtimate upon them for the difference.

J. SMEATON.

Auſthorpe,
19th *February* 1772.

BRIDGES AT BEWLIE, CONON, ALTGRAN, &c.

THE REPORT of JOHN SMEATON, Engineer, upon fundry Matters referred to him by a Minute of the Board of Truftees of annexed Eftates, dated 29th January 1770; as alfo by the Letter of Mr. Secretary Barclay, of 17th July 1771.

The feveral fubjects are as follow:

(Board's Minutes, 29th January 1770.)

Bridge over the River Bewlie.
Do. - - Conon.
Do. - - Altgran.
Harbour or Landing Place at Portleich.
Mills and Watercourfe of Miltoun of New Tarbet.

(Mr. Secretary Barclay's Letter.)

Stone Piers at the Ferry of Inverbreakie.

HAVING carefully viewed the above fubjects in the month of Auguft 1771, I tranfmitted to the Honourable Board plans, directions, and eftimates for conftructing the three bridges comprehended in the three firft mentioned articles, on the 19th of February laft; but being in the courfe of this bufinefs fuddenly called away to London upon affairs relative to the Grand Canal, as I then by letter informed the Board, and having been by a fucceffion of preffing affairs occupied ever fince, it is only now that I am able fully to acquit myfelf of the above articles.

What regard to the three firft articles I have in a great meafure delivered myfelf upon as above mentioned; it only remains that I affign my reafons for preferring the fituations for which thefe plans are refpectively drawn.

Refpecting the River Bewlie.—The river at the prefent ferry is not only much wider and deeper than at the place propofed at Dumballoch, but being much more in the tide's way, would on that account alfo be more expenfive; and furthermore as the river feemed to threaten

threaten to break through the neck of the loop, at the extreme bend of which is the ferry, it might thereby happen that the bridge would become deferted; and if the bridge were originally built upon this neck, the cutting of the neck and forming a dam acrofs the river at the prefent ferry, with a road upon it of fufficient height to be out of the water's wafh, would be in itfelf a confiderable expenfe. At Dumballock the river has a fair run, is moderately wide and deep, and has a good gravel bottom, and as I am informed that it will not carry the road much about, I think upon the whole that this place is to be preferred to any that was pointed out to me for the fituation of a bridge over the river Bewlie.

The fitteft place for a bridge over the river Conon has been by the country in general judged at the place called the Rock. The reafon why I did not think this place proper I gave in my letter of 19th of February laft, which accompanied the plans and eftimates, and which, to fave trouble of a reference thereto, I here repeat: "That I find the total "length of a bridge there (at the Rock) will be greater by almoft 50 feet than where I "propofe it; and that it will require one arch to be built of 114 feet fpan, and as the "water is very deep underneath, it will require fo great an expenfe to center and con- "ftruct fuch an arch, befides making good the paffage over the remainder of the river, "which is almoft 200 feet more, that I apprehend it is far more eligible to conftruct the "bridge in the place I have fixed upon, where there is a fair and open run of the "river.

"The Rock, as fo called, being a kind of concreted gravel, which appears in a degree "to wear away by the action of the water, it is in no ways certain that the river may not "in part undermine the foundation of fo great and neceffarily heavy an arch, and which "from the depth of the water it will be difficult to guard againft by artificial means."

Befides the place I have propofed, viz. at the Boat of Braan, there is alfo another fituation weftward, at the Turner's Boat of Braan. This is fo nearly equivalent with the former, that the fame defign would fuit either place; but by being further weftward, I apprehend it muft take travellers further round, the paffage at the common ferry over Conon being eaftward of all thofe places.

Refpecting the paffage of Altgran, there is no choice; there is already a weak timber bridge which may occafionally take over a horfe.

PIER or Landing-place at Portleich.

PORTLEICH is situated upon the north west side of the bay of Cromartie, which is in the whole so entirely land-locked, that there cannot at any time be any great sea, such as places adjoining upon the ocean are subject to. The bay of Cromartie may therefore in the whole extent of it be justly considered as a safe harbour; however, being some miles broad, it sometimes happens that there is a greater swell raised within itself than is agreeable to vessels lying upon the ground at low water to deliver or take in a cargo. The shore at Portleich lying upon a very gentle slope, and the tides being rather short, as not exceeding 11 feet at common spring tides, it happens that in order to get a very moderate depth of water at high water, it will be necessary to advance the pier or landing place a considerable way from the high water mark into the bay. A pier therefore of the length of 188 yards, will but barely reach from high to low water mark at spring tides; so that alongside this pier head, which I propose to be the landing place, there will be about 11 feet water at spring, and about 7 or $7\frac{1}{2}$ feet at neap tides. About 24 yards next the pier head is designed to be of 12 feet broad at top, so as to be convenient for a landing place for vessels to lie on either side, the rest of the pier being only 9 feet broad at top, is considered only as a causeway for making a communication for carriages between the shore and the landing place; but will be very useful in sheltering fishing boats, for the sake of which a few large whinstones are roughly thrown together. The new pier is proposed to take its commencement from a stone that I marked when there, a little to the westward of the present landing-place, and to extend in a direction towards the castle of Cromartie; so that vessels which while unloading want to take the shelter of the pier may lie on either side thereof, according to the wind and season of the year. As the shore is a muddy kind of sand, and a very flat slope, a pier run out in this manner, by intercepting the circulation of the water, may gather mud on each side of it; but to prevent its gathering near the head in the part joining the causeway to the pier head, two arched perforations are left, through which the seas and current acting will be the most likely means of preventing the gathering of mud near the pier head, where the water is most required to be deep. The foundation of the pier is supposed to be laid originally one foot under the surface of the sand, so that being 15 feet in the whole height, it may be allowed to settle one foot more in the sand, and yet remain two feet above the high water of spring tides, which I apprehend where the seas are so moderate as in the bay of Cromartie, will be a sufficient elevation.

In

In regard to the estimate of this, as well as for the rest of the proposed works, the only thing that I can be certain of is the quantities, for the prices depend so very much upon the kind of workmanship employed, and carriage, that I cannot be at any certainty about them. Where the carriage does not exceed a mile by land or five or six miles by water, I apprehend the prices I have annexed will suit, on a supposition that labour is not dearer in the shire of Ross than in the south of Scotland.

ESTIMATE for building a Pier or Landing-place at Portleich, upon the Bay of Cromartie.

	£.	s.	d.
THE pier head, comprehending 78 feet in length, to be 15 feet broad at bottom, 12 feet top, and 15 feet high from the foundation, at a mean thickness of two feet outside, will contain 6620 cube feet of rough scappeled block freestone, which being laid dry, the quarrying, freight or carriage, and building, at 5d per foot - -	137	18	4
To 340 cube yards of quarry rubble or broken whinstones, for filling the body, winning, freight or carriage, and laying in place, at 1*s*. 6*d*. per cube yard	25	10	0
To cramps and lead for confining the corner stone at the termination of the pier head - - - - -	1	0	0
The pier head or landing place	164	8	4
To continuing the pier or causeway from the landing-place above mentioned to the shore, being 162 yards in length, and 9 feet broad at top, which at the mean thickness of 18 inches, will contain 21,141 cube feet of scappeled free stone, at $4\frac{1}{2}d$. - - -	396	7	10
To 1062 cube yards of quarry rubble or broken whinstones for filling the body, at 1*s*. 6*d*. per cube yard - - - -	81	13	0
To extra work in the two arches - - -	4	0	0
	482	0	10
Sum of the above, being the neat estimate - -	646	9	2
To contingencies at 10 per cent. - - -	64	12	11
Total	711	2	1

The

The MILLS and Watercourfe to the Mills of Miltown of Newtarbet.

The mills of Milltown of Newtarbet are indeed in very bad repair, and need rebuilding; but fo far as I can learn, when in repair are fufficient to anfwer the purpofes; and as their method of grinding in that part of the world is in a particular way, which their conftruction of mills is adapted to anfwer, I cannot venture to give any new defigns, which might require different millwrights and millers to what the country furnifhes, to make them fucceed, and at laft probably not give fatisfaction: I therefore refer the Board to get their mills rebuilt in the moft fubftantial way that is in practice in the country where they are, as foon as a proper fituation can be fixed upon. The matter here, which is moft preffing, and about which fome advice is the moft neceffary, is the dam head, by which the water of the river is turned into the watercourfe or lead from thence to the mills. The dam head and watercourfes, as relative to the fituation of the mills, muft be looked upon as a very remarkable piece of projection, for after raifing a dam head to about three feet, to an extent of 250 feet in length, acrofs a river that in general is not above 50 feet wide, and after conducting the water along the face of the rocks, in an aqueduct built up with fods, which are perpetually failing and tumbling down, it is in a courfe of about half a mile in which there is a fall of about 20 feet, ultimately conducted to the troughs of the mills, from whence to the bottom of the wheels there is *only about* 11 *feet of fall* made ufe of after lofing twice that quantity by the road; fo that it would feem that the original projector had extended his watercourfe upon the river in order to meet with difficulties: had the work been permanent there had been no error, but a lofs of fo much labour in the firft erection; but the misfortune is, that the dam head being only built with loofe ftones, it is broken by every fpeat that comes down the river, and as certain tenants are obliged to build it up as often as it comes down, and fometimes obliged to work up to their middles in water, even in winter, it becomes not only a heavy burthen upon them, but a great interruption to doing the bufinefs of the country, that is thirled to thofe mills.

Two ways offer themfelves to avoid thefe inconveniences, one is, by building a new dam head near the place where it now is, and removing the mills; the other, to build a new dam head at a new place, and conducting the water to the place near thereto, that may be more convenient. By reference to the plan made by Mr. David Aitken the furveyor, it appears, that if inftead of the dam head, which turns the water into the prefent

prefent head, a dam head is erected higher up, and a new lead or watercourfe cut on the other fide of the river, in the direction that the mills can have a fall into the river there, which he makes to be no lefs than 18 feet 3 inches, which indeed is more than fufficient for the purpofe of the mills, they having now in effect only 11. The objection that occurs to me is as follows: A part of the pleafure-ground, or policy of Balganoun, lies contiguous to this dam's head, and the ground on that fide being elevated fcarce 18 inches above the level of the water in the dam, would be very liable to be overflown by the pen of the prefent dam in fpeats, were it not for the great length of the dam which takes off the water in a fheet of no lefs breadth than 250 feet, and generally in the greater fpeats breaks down. But were this water pent up by a dam, whofe length will be no more than 84 feet, according to Mr. Aitken, the water will be confined in fo narrow a compafs, in proportion to what it occupies at prefent, that it would undoubtedly be more liable to overflow the policy above mentioned: whatever damage may happen to the policy by the prefent dam, it may, as I apprehend, be prefcribed for; but in cafe the fituation of the dam be changed, or the dam itfelf altered, if the laws of Scotland are in fuch cafes parallel to the laws of England, fuch new dam cannot be prefcribed for, but muft be liable to all damages that may arife from it. In order, therefore, that the dam and watercourfes may be clearly freed from the poffibility of litigation, I obferved that there was no kind of neceffity to bring the water from the old dam, but that the level would admit of the water's being taken up even below the bridge where the Cromartie eftate extends on both fides, and can be conveyed into fome part of the prefent lead before it arrives at the mills, and confequently, that the fituation and power of the mills will remain the fame as now. The furveyor reports, that from the fuppofed new dam head to the furface of the water in the mill lead, is a fall of 8 feet 2½ inches; he does not clearly diftinguifh whether he fuppofes the dam head raifed up to the level of a marked joint of the middle pier of the bridge, which he fays is 3 feet ¾ inch higher than the furface of the ground at the place propofed by me for the dam head; but fuppofing the level taken from the faid joint of the pier (as the moft unfavourable fuppofition), if we caft off the 3 feet ¾ inch for the height of the faid joint above the faid ground, and (if need be) two feet more to bring the dam's crown within the land, there will ftill remain three feet of defcent from the dam head, through the new part of the watercourfe into the old one, which in a courfe of 550 yards is more than fufficient; it therefore follows, that the new dam head need not be raifed more than is fufficient to divert the water into the new watercoufe, and there appears to be a fall of full four feet to the head of the mill troughs, if the mills were rebuilt, where there feems to have been formerly a walk mill, this four feet might be added to the prefent fall of 11 feet, and make 15, which would caufe the mills to work ftill more brifkly; but

but if the present situation is found more commodious, the fall at the mills may be considerably increased by raising one of the banks some part of its length.

The design for a dam head, that I have given, amounting to 180l., supposes the work to be done in the most substantial manner, and so as to be likely to be permanent; but as it appears to me, that a few flat stones set upon the edge, so as to form a line across the river, might be sufficient to divert the water into the new watercouse, and the work may be done in this way, in case the Board is willing to save a good part of the outlay, by subjecting the work to small derangements by floods.

ESTIMATE for a new Dam Head and Watercourse for the Mills of Miltown of Newtarbet.

	Cubit feet.	£.	s.	d.
To fir timber in bearing piles, plank piles, string piece and cover, containing	209			
To oak and fir timber in the sluice - - - - -	17			
Timber in the whole, at 4s. per foot, wood and workmanship, and measured neat in place - - -	226	45	4	0
To iron work in the whole - - - -		3	0	0
Carpentry total -		48	4	0

MASONRY.

	Roods.	£.	s.	d.
To casting foundations - - - -		3	0	0
The dam's end wall to be four feet thick, and supposed eight feet high from the foundation, being 96 feet long, will contain - - -	4¼			
The flue walls within and without the clough or sluice, being two feet thick and four feet high from the foundation, and in the whole 70 feet long, will contain, say - - - - - -	1			
Roods of rubble masonry at 5l. 10s. - - -	5¼	31	12	6
To allowance at 3d. per foot, face measure, upon the dam's end wall next the water, and on the top to allow for larger stones, caping and rough working the same, 1152 feet - - - -		14	8	0
Carry forward		49	0	6

	£.	s.	d.
Brought forward	49	0	6
To freestone scappeled for the surface of the dam, 72 feet long, 19 feet broad over all, and at a medium of 18 inches deep, will contain 2052 cube feet, at 5d.	42	15	0
To 72 yards cube of quarry rubble, or broken whinstones for filling the body and securing the skirt of the dam, at 1s. 6d. - - -	5	8	0
Total of masonry -	97	3	6

SPADE-WORK.

	£.	s.	d.
To cutting a new aqueduct of five feet bottom, supposed three feet mean depth, with proper slopes, 555 yards running, at 6d. -	13	17	6
To banking across the flat from the dam's end west to the high ground, being about 27 yards long, 3 feet top, slopes as 3 to 1, to be covered with sods, containing 234 cube yards, at 4d. - -	3	18	0
Total of spade work	17	15	6

ABSTRACT.

	£.	s.	d.
Carpentry and iron work - - -	48	4	0
Masonry - - - -	97	3	6
Spade-work - - -	17	15	6
Neat estimate	163	3	0
To contingencies, at 10 per cent. - -	16	6	4
Total	179	9	4

The PIERS, or Landing-places, at the Ferry of Inverbreakie:

On this head I am desired by Mr. Secretary Barclay's letter of 17th of July 1771, "to "examine into the state of the above ferry, and consider the propriety and utility of "building the pier proposed." The ferry of Inverbreakie is situated upon a narrow part of the bay of Cromartie, somewhat similar to Queensferry upon the firth of Forth, but I believe not half the width of the latter; and as the bay of Cromartie is land-locked on every side, and the tides rise and fall far less than at Queensferry, there is accordingly far less swell and strength of tide; of consequence the ferry of Inverbreakie is by *nature* attended with fewer inconveniences than Queensferry. The two

two ſhores at Inverbreakie are upon a moderately quick decline from high water till about the low water of neap tides, after that there is a flat ground on both ſides, and for a conſiderable extent upon the ſouth ſide, which at low water ſpring tides lies dry. The conſequence is, that whenever the water over the ſaid flats becomes too ſhallow for the boats to go over them, the ferry is altogether inacceſſible to the land except for foot paſſengers, who may then be carried over the flats on men's backs; and as there is no ſort of piers, landing-places, or projecting rocks or any other than a ſloping beach, it is not a very commodious ferry for the boating of *horſes* at any time, and as to carriages, it ſeems altogether impracticable, without taking the carriages to pieces. As I went to Miltown of New Tarbet from Invernefs by way of Bewlie and Dingwall, and returned by the ferries of Inverbreakie and Keſſack to Invernefs, I had a kind of practical proof of the utility of theſe ferries, and beg leave to ſay, that were the equipment of the ferries of Keſſack and Inverbreakie for taking in horſes and carriages, as complete as they might be made, no travellers into the eaſtern parts of the ſhire of Roſs, &c. would go the other road, except thoſe who would rather go 20 miles round than croſs any water at all; and even there are two ſmaller ferries where the inconveniences of embarking and debarking are almoſt as great, greater indeed than at Keſſack, where there are already tolerable landing-places made by art on each ſide, though not ſo good as they might be rendered. The main difficulty therefore at preſent is at Inverbreakie, where if two ſtone piers or landing-places were run out from the ſhore on each ſide, viz. to the length of 80 yards on the ſouth ſide, and 100 yards on the north ſide, this ferry would become practicable for travellers at all times, except for about two hours at the low water of a ſpring tide. The length of 100 yards on the north ſide will carry out the pier far enough to enable the boats to work at low water of ſpring tides; but to do the ſame on the ſouth ſide would require that pier to be extended 70 yards further than above propoſed. But as thoſe flats ſeem to be compoſed of nothing but an oozy kind of ſand, I am in hopes that as thoſe piers will in a ſenſible degree increaſe the motion of the water over them, there is a chance that the remainder of the flat ſand extending beyond the ſouth pier towards the north, may be removed by that increaſe of the current. It will however very greatly contribute to the utility of the ferry to have the piers carried to the extent above ſpecified; and which may be afterwards extended in caſe the utility thereof to that part of the kingdom demands it.

ESTIMATE

ESTIMATE for the Landing-places at the Ferry of Inverbreakie:

	£.	s.	d.
The landing-place being at a medium of ſix feet high from the foundations, 10 feet broad at bottom, and eight feet at top, will contain of ſcappeled freeſtone, at a mean thickneſs of 18 inches in one yard, 90 feet cube, at $4\frac{1}{2}$*d.* -	1	13	9
To $2\frac{2}{3}$ yards of rubble for filling the body, at 1*s.* 6*d.* - -	0	4	0
Neat eſtimate per yard running -	1	17	9
Ten per cent. for contingencies - - -	0	3	9
Total per yard running - -	2	1	6
To 180 yards of pier or landing-places, including both ſides of the ferry of Inverbreakie, at 2*l.* 1*s.* 6*d.* - - - -	373	10	0

N. B. As there is water-carriage from eminent quarries upon the Cromartie bay, it is likely this work may be contracted for to be done conſiderably cheaper.

SUTTON BRIDGE.

THE REPORT of JOHN SMEATON, Engineer, upon the Deſign for a new Bridge over the River Hull, near Sutton.

HAVING inſpectedthe deſign for a Turning or Swing Bridge, intended to be built over the river Hull near Sutton, and which was exhibited to me by the direction of Meſſrs. Pool, Watſon, Etherington, and Page; and the queſtion being, Whether it will, and in what manner, affect or endanger the flooding of the grounds in Holderneſs, or the navigation of the ſaid river? I am of opinion as follows:

That every bridge may be conſidered in ſome degree an impediment to drainage and navigation; yet being a work of public utility, it ſeems to me, that it cannot be properly objected to where the riſk is ſmall and the advantage adequate: reſpecting drainage, the principal objection that appears to me will be by ſtopping the ice upon the breaking up of a froſt, which all timber bridges built on piles are in ſome degree apt to do; but the river Hull being a ſlow running river, will not be ſo ſubject to form ſuch obſtructions as thoſe that run more rapidly. The bridges from Fulham to Putney, at Kingſton, Staines, Maidenhead, and Henley, over the river Thames, thoſe at Beal and Haddleſey over the river Aire, thoſe on the Dutch river over the river Dun, and that at Hull over the river Hull, are ſo many inſtances among numberleſs others of the ſame kind; and though it ſometimes happens, yet it does not ordinarily happen that the ice is ſtopped thereby.

I ſee no objection to it in point of navigation, but the trouble of opening it; but I look upon a moveable bridge as a leſs hindrance to veſſels than a fixed one; and, I believe, it was never ſupported as an objection to the building a bridge, viz. that of the river being navigable. I take it for granted that the width of 22 feet is ſufficient for the paſſage of all veſſels that can go there, otherwiſe it ought to be made ſo; and, I think, it ought to be made ſo high that veſſels may go under it, in caſe of the turning part happening to be out of order.

J. SMEATON.

Auſthorpe,
7th *Feb.* 1772.

WALTON BRIDGE.

THE REPORT of JOHN SMEATON, Engineer, upon the State of Walton Bridge, as it appeared upon a View taken in July 1778.

THIS bridge having been built with the greateſt care and circumſpection under the care of that eminent artiſt Mr. Etheridge, and of the very primeſt timber that could be procured, and which having been finiſhed not many more than 20 years, before it diſcovered ſigns of failure, is a monument of the fallibility of all timber conſtructions where great weights and preſſures are concerned.

I found the four middlemoſt diviſions of the great arch ſupported by four rows of pillars raiſed upon a ſcaffold, which were ſupported by four rows of piles driven into the bed of the river, by which means the great arch appeared ſufficiently ſecured from any further failure that was likely to happen in a ſhort time, and this at the ſame time furniſhed the means of examining that part of the bridge which, by the decay of ſome particular pieces of timber, was in a likely way to have fallen into ſudden ruin.

I examined every part of the bridge as carefully as I poſſibly could, and as nearly as I could come at them; and it appeared to me, that the timber in general was as perfectly ſound, and much more hard than it was when the bridge was erected: but in the part where the firſt ſymptoms of complaint had ſhewn themſelves, I found ſome parts of the timber ſo perfectly rotten and decayed, that it was reduced even lighter and leſs connected than touchwood, at the ſame time that the remaining part of the ſame pieces appeared perfectly ſound; and this decay taking place at a critical point where ſeveral pieces were aſſembled, and thereby looſing the geometrical bond and dependence of one part upon another, at the ſame time that it was in a way inevitably to have brought down the whole of the great arch, it proves that the decay was not owing to the fault of the particular pieces concerned, but to their local ſituations, of which effect we will now enquire the cauſe.

The great arch being 130 feet ſpan, and originally not above 27 feet riſe above the ſpringers, muſt, as an arch, be conſidered as a very flat one, but as there is in the very crown of the arch between 10 and 11 feet in height from the under ſide of the arch pieces

pieces to the upper ſide of the hand-rail, this affords a ſpace that in geometrical timber framing would have a very great degree of ſtiffneſs independent of its riſe as an arch, ſuppoſing it not to be overpreſſed with weight. The main ſtrength therefore of this bridge has been intended by its architect to conſiſt in the ſtrength of the two geometrical frames, making the two ſides or external faces of the bridge; between and from which frames he has ſuſpended a floor by ſtrong ſtraps of iron, at every diviſion of the arch; and as he has propoſed to cover this floor with a conſiderable thickneſs of gravel, which amounted to upwards of 100 tons burthen, over the opening of the great arch, it ſeems that he has conſidered that the laying plain beams acroſs from ſide to ſide with about nine tons of gravel upon each beam near the middle of the bridge, excluſive of the weight of the timber work, would be ſo great a burthen as to cauſe the beams to ſag, and totally to fail when they became a little tainted; he has therefore upon the middle of each of theſe croſs beams erected a king poſt, in the way of the king poſt of the principals of a roof, and ſupported theſe king poſts by oblique ſtrutts or truſſes on each ſide, footed into the croſs beams near the ends, ſo that theſe croſs beams will reſemble the tie beams of a roof, the ends of which, inſtead of being ſupported upon a wall, are ſupported, as has been ſaid, by ſtrong iron ſtraps from the ſide frames. Now as the riſe in the king poſts is but ſmall, the ſide truſſes or ſtrutts will act very obliquely, and therefore to ſupport the king poſt, and in conſequence the middle of the floor, with its ſuperincumbent weight of gravel, thoſe ſtrutts will require to be very firmly footed into the croſs beams near the ends, and on this account require to be ſunk a good depth into the croſs beams, in order to make the footing good: again, near the middle of the bridge, the upper ſurface of the croſs beams will be nearly horizontal, ſo that any wet that in time of rain percolates through the gravel and makes its way down thoſe oblique ſtrutts, to adjacent parts, will run into thoſe footings, and there not being able to eſcape or ſuddenly to dry, cannot get out but by a ſlow evaporation in dry and warm weather; this producing a fermentation, it is eaſily ſeen that in thoſe parts ſo ſituated a ſtrong tendency to rot muſt take place, while in thoſe croſs beams further from the middle of the arch, their upper ſurface being more inclined to the horizon, the wet will lodge in a leſs degree, and conſequently they will be leſs ſubject to rot. It is alſo eaſy to ſee that ſome of the timbers ſimilarly ſituated by accidental circumſtances in the cover, being ſome more, ſome leſs liable to take the rot, even though the quality of the timber was all alike. It is further neceſſary to explain, that beſides the intention of ſtrengthening the floor by the truſſing abovementioned, in the middle of the bridge a ſet of ribs are thrown in and abutted one againſt another, ſo as to form an arch upon the ſame principle as the under ſet of arch timbers do on the outſide; but as theſe ribs ſo thrown in, cannot be connected with exterior timbers in the manner the outſide ones are connected,

nected, and framed with the hand-rail, the middle rib therefore conſiſting of ſingle timbers for three or four bays in the middle of the bridge, till they get more cover, can there afford but a feeble additional ſupport in proportion to the ſtrength of the outſide frames. This being premiſed, it will readily be conceived, what in reality has proved to be the caſe, that the footing of the ſtrutt with the croſs beam, being the ſecond from the middle towards the Middleſex ſide, on the down ſtream ſide of the bridge, being totally rotted through both ſtrutt and beam, this end of the beam will ceaſe to be ſuſpended by the iron ſtraps and the weight of the floor, and bed of gravel will become diſcharged almoſt immediately upon the middle rib, which being ſingle, though perfectly ſound, was ſprung in the middle, that is, ſo far broken as to have loſt the greateſt part of its ſtrength by large ſplinters thrown off on the under ſide. The failure of this rib again in part diſcharged the weight upon the adjacent croſs beams, which being alſo decayed, though not perfectly rotten, muſt ſoon have given way in like manner as the former, had not the application been made in due time by the ſupports under the moſt weak and decayed parts, as I found it, which giving time for conſideration, the queſtion now is, what to do with it?

On examination I found all the truſs footings at both ends of the four middle croſs beams to be tainted, and ſome of them conſiderably decayed, as well as that which was totally ſo, and cauſed the immediate failure. As the ſcaffold did not extend further, I could only judge of the ſoundneſs of the adjacent croſs beams from viewing them at the diſtance of 10 feet; and as I found the reſt of the timber work in general very little decayed, the parts particularly ſpecified and examined excepted, I am in hopes the taint in the parts I have mentioned has not extended in any great degree much further. It ſeems therefore to me, that as the greateſt part of the ſtructure remains perfectly ſound, and the decayed parts capable of being reſtored, ſtrengthened, and ſupported at an adequate expenſe, by means of the ſcaffold already erected, it would not be for the intereſt of the proprietor to make at preſent any material change in the ſtructure, as a repair judiciouſly conducted may be very well expected to make it laſt for a term equal to what it has laſted already; and then it will be time to conſider whether it may be worth ſupporting, by throwing another pier into the middle of the river, and thereby making the great arch into two, covered with wood, brick, or ſtone, as may be then adviſed.

I look upon it that the preſent temporary ſupport, excluſive of the deformity it gives to ſo noble a ſtructure, might be effectual for ſome years to come, could it be ſecured againſt injury from ice floating down the river at the break of a great continued froſt; the effects

effects of which, on the arrival of such an event, cannot, I think, be ascertained before hand; there appears, however, a reasonable time for consideration.

When this bridge was undertaken, I apprehend it was the boldest design of the kind that had then been executed, at least in this kingdom; and the principles of its construction carried to a greater extent than had before been experienced. It is not therefore to be considered as wonderful, that after the term of years that has elapsed since its construction, errors have shewn themselves that probably would not have been foreseen by those who now can readily see them, but which in this repair I would as much as possible endeavour to relieve.

The first and greatest error of all was in making so large a middle arch. Had this bridge consisted of three arches more nearly equal, or rather of five arches, and equally well performed, in all probability no material derangement would have happened in the course of a century. The great span of the middle arch made it desirable to make it as flat as possible, otherwise it would have been impracticable to have driven carriages over it;—as it is, though in reality too flat for the span, yet it is still too steep an ascent for loaded carriages, because in their descent they are obliged to drag, and this makes it necessary to keep a cover of gravel much thicker, and consequently much heavier than would otherwise be necessary, and this again, together with the flatness of the arch, so very greatly increases the natural pressure, that overcoming those of the side arches, it makes both the piers lean to landwards, and also lays so great a stress upon the bed timbers which the arch pieces rest upon, that their ends are perfectly sunk into the bed timbers, so that from the whole of the pressure sideways, the crown of the arch is come down above two feet in perpendicular height; and I look upon it, that these are consequences of errors in the first construction, independent of what has happened by the rotting of the timbers; again, the weight of the cover has produced the idea of trussing the cross beams, and this again has brought on the rotting of the beams and strutts at their junctures: I would therefore recommend the following mode of repair:

1st, In those cross beams that need shifting, I would recommend to use whole beams without trussing, and rather to fill up the spaces by doubling the beams than the use of strutts; the timbers being thus unwounded will be less subject to retain moisture and rot.

2dly, I would remove the gravel totally from above the nine middlemost bays of the middle arch; and therewith by increasing the height and length of the slopes, reduce

the general declivity, and by bringing a greater weight over the side arches, enable them more nearly to counterbalance the lateral pressure of the great arch. This middle space thus laid bare, I would cover with sea coal cinders such as are collected by the dust carts, and sifted near London, for the purpose of burning bricks; and this cover of cinders being gradually reduced to about six inches thick at the crown of the arch, by this means, I think, that near about 40 tons weight may be taken off from the middle of the great arch; for the cinders being much lighter than gravel, and sticking together much more closely, a less thickness is necessary, and by easing the descent, the dragging over the great arch may probably be prevented, or at least rendered less detrimental.

3dly, By way of a general strengthening of the whole of the great arch, I would advise under all the arch timbers between the radius pieces, to chock in balks of fir, and to tighten every piece separately by oak wedges, and when all are in, to tighten up the whole, nailing lead or copper plates over the joints to keep out the wet, and this I would advise to be done with respect to the middle ribs, or arch pieces, as well as the outsides; all which having fair footings cut into the stone of the pier, above the cordon, will also greatly relieve the pressure of the present arch timbers upon their bed timbers.

J. SMEATON.

London,
30th *March* 1779.

ESTIMATE for building a brick Superſtructure upon the preſent Piers, with the addition of a new Pier in the middle of the River, for a Bridge over the River Thames at Walton in Surrey.

	£.	s.	d.
To clearing and preparing the foundation for laying down a new pier in the middle of the river, ſuppoſe - - - - - - - -	40	0	0
To conſtructing a caiſſon and bottom for the pier to reſt on - - - -	136	9	0
To the conſtruction of two centers for turning the arches, and removing each of them into a new place - - - - - - -	339	8	0
Preparing the foundation, and carpentry, and iron-work	515	17	0

THE PIER.

	£.	s.	d.
To caſe the ſame with Purbeck aiſler will contain 2396 cube feet, which if ſet in place, at 3*s.* per foot, will be - - - - - -	359	8	0
The inward caſe or filling of ditto with grey ſtock brick, and terras mortar quite ſolid, will contain 2548 cube feet, which at 13*d.* per foot - - - -	138	0	4
Maſonry and brick work	497	8	4

THE ARCHES.

	£.	s.	d.
The two great arches, at 2½ brick thick, will contain $22\frac{7}{10}$, ſay 23 rods of brick work, entirely of grey ſtock quite ſolid, in good mortar, at 8*l.* 15*s.* per rod, - -	201	5	0
The two leſſer arches, at ſame thickneſs, will contain 18 rods of works, at 8*l.* 15*s.*	157	10	0
The four new arches	358	15	0
The ſpandrell walls, to be at a medium two bricks thick, completely faced with grey ſtock bricks outſide, will contain in 270 feet length on each ſide, in the whole 37 rods of work, which at 8*l.* per rod - - - - -	296	0	0
The walling and vaulting in order to fill up the ſpandrells between the arches and ſupport the gravel road, will contain 42 rods of the beſt place brick work, at 7*l.* 7*s.*	308	14	0
To ſpandrell walls and vaulting to ſupport the road	604	14	0
To 540 feet running of Portland ſtone wall caping for the parapets, to be 8 inches thick, will contain 660 cube feet, which laid on and cramped, at 4*s.* 6*d.* per cube foot, will come to - - - - - -	148	10	0
To flagging a walking path on each ſide with Elland edge flaggs, two feet broad, and 270 feet long, will contain 1080 feet, at 1*s.* - - - -	54	0	0
To 550 loads of gravel to form the road, at 1*s.* - - - -	27	10	0
To caping, paving, and gravelling	230	0	0

AB-

ABSTRACT of the preceding ESTIMATE.

	£.	s.	d.
Preparations for the foundation, caiſſon, and centers - - -	515	17	0
Maſonry and brick work in the pier - - - - -	497	8	4
The four new arches - - - - - - -	358	15	0
The ſpandrell walls and vaulting, to ſupport the road - - -	604	14	0
To caping, paving, and gravelling - - - - - -	230	0	0
Neat eſtimate	2206	14	4
To allow for contingent expenſes 10 per cent.	220	13	5
Total	2427	7	9

N.B. The above ſuppoſes the bottom of the river to be a gravel of ſufficient conſiſtence to lay down the pier without piling, as the former piers appear to have been, and alſo thoſe of Weſtminſter Bridge.

No allowance is made for taking down the wooden ſuperſtructure, as the value of the timber when taken down, will be much more than the expenſe.

HARRATON BRIDGE.

ESTIMATE for a Scaffold Bridge on Stone Pillars, at Harraton upon the River Wear.

	£.	s.	d.
To making coffer dams for keeping off the water for the four foundations -	116	11	0
To digging and framing the four foundation pits to found upon the stone head	60	0	0
To making a horse chain-pump - - -	60	0	0
To works of horses and drivers in drawing the four foundation pits -	63	0	0
To clearance for the masonry	299	11	0

MASONRY.

	£.	s.	d.
To 1088 cube yards of terras rubble work in the four square foundations to support the pillars, at 9*s.* per cube yard - - - - -	486	0	0
To 3100 cube feet of terras work cased with aisler at 6*d.*, to bring the work above low water - - - - - - - -	77	10	0
To 627 cube yards of aisler building in the superstructure, at 4*s.* - -	125	8	0
To 640 cube feet of aisler work in the parapets of the terminating pillars, at 7*d.*	18	13	4
To lead and iron in cramps for the masonry - - -	20	0	0
	727	11	4

CARPENTERS.

	Feet.	£.	s.	d.
In the two great truss beams,	882			
In the cross beam, standards, &c.	485			
	1367 at 2*s.* - - - -	136	14	0

SMITH'S WORK.

	£.	s.	d.
To 8¼ cwt. in 60 main bolts at 50*s.* per cwt. - - -	20	12	6
To 5½ do. in spike nails, &c. at 42*s.* per cwt. - - -	11	11	0
	32	3	6

PLUMBER'S WORK.

	£.	s.	d.
To sheet lead to cover the two main truss beams, 28 cwt. at 1l. 1s. -	29	8	0

AB-

ABSTRACT.

	£.	s.	d.
Preparing foundations - - - - -	299	11	0
Masonry - - - - - - -	727	11	4
Carpentry - - - - - -	136	14	0
Smith's Work - - - - - -	32	3	6
Plumber's work - - - - - - -	29	8	0
Neat estimate	1225	7	10
Add 10 per cent. for contingent expenses - - -	122	10	9
	1347	18	7

Lambton,
26th *June* 1783.

ESTIMATE of the Stone Arch and additional Pier.

	£.	s.	d.
To sinking and timbering the foundation pit - - -	13	5	0
To drainage of the water - - - - - -	15	0	0
To 270 cube yards of rubble in terras - - -	121	10	0
To 775 cube feet of aisler in terras, at 6*d.* per foot - - -	19	7	6
To 157 cube yards of aisler building, at 4*s.* - - -	31	8	6
To 810 cube feet in the arching, at 7*d.* - - - -	23	12	6
To 1152 cube feet in the spandrells and parapets, at 7*d.* - - -	33	12	0
Neat estimate	257	15	0
To 10 per cent. for contingent expenses - - -	25	15	6
	283	10	6

J. SMEATON.

Lambton,
27th *June* 1783.

METHOD

METHOD of founding and building the Stonework of Harraton Bridge.

The Method of founding the two Land-breaſt Pillars of Harraton Bridge upon the Stone Head, as follows:

THE ſtone head at the north pillar lying but about eight feet, and the ſouth pillar ſomewhat exceeding twelve feet below low water-mark, I ſhall confine my remark to the ſouth pillar, becauſe what will do for that will become perfectly eaſy as to what concerns the north pillar.

The ſouth pillar being conſiderably within the bank, I would ſet out the pit about 18 inches or two feet wider on each ſide, and longer at each end than the intended foundation; and then going down perpendicularly, I would ſupport the ground by framing in the manner of a common ſquare pit or ſhaft; but as the bearings on the ſides would be 30 feet in length, I would not only make the ribs pretty ſtrong (ſuppoſe half balks,) but ſupport them with two or three ſetts of croſs-ſtretchers, and then get out the matter with corves and baſkets, till you get down to the ſtone head, carrying down the frame, and putting in new ribs as often as you find neceſſary from the looſeneſs of the matter, as you do in ſinking a pit.

The ſtretchers may either be borrowed back or walled in, and the greateſt part of the framing may alſo be borrowed back, the ground tier of ribs excepted, which may alſo be avoided by driving down boards endways as ſoon as they will reach the ſtone head.

The two pillars in the bed of the river I would get down to the ſtone head, by driving a caſe or coffer dam of rebated piles down to the ſtone head; for the deeper pillar which is the ſouth one, the piles would not want driving above 9 feet into the ground before they would come down upon the ſtone, and the piles being 20 feet in length, would reach above high water mark. Theſe too flat ſides when the water was pumped out, would want ſupporting with croſs-ſtretchers, as deſcribed in the foundation pits for the land-breaſts.

I would compoſe each ſide of this caſe of whole timbers well ſhod with iron, to make them enter the ſtone, if of a ſoft quality, and thereby get the better footing. The intermediate ſpaces I would fill up with half timbers rebutted edgeways, and into the main timbers, ſo as to form in the whole one ſolid ſheet; this would greatly eaſe the pit of water,

water, that would otherwiſe be produced, and from the inſide of this caſe to get out the matter ſo as to found upon the ſtone head.

What will greatly contribute to facilitate all theſe operations, will be to have pump-machinery quite maſter of the water, and for this purpoſe it will be well to have two pumps, one for each end of the pit, but which may each be worked by the ſame horſe work, ſo that the water may readily drain each way, and each be ſerviceable if the other is out of order.

The piles compoſing a caſe for the ſouth pier will afterwards do for the north, and after all, the timber will be very little the worſe for uſe.

CONSTRUCTION of the Maſonry for Harraton Bridge.

The ſquare foundations, ſuppoſed to bring the ſolid work up to the bed of the river, comprehended in the 1080 cube yards of terras rubble in the eſtimate, I ſuppoſe to be compoſed chiefly of blocks, flatted and bedded with the hammer, ſo as to make them lie flat, and being all of a height in the ſame courſe, the interſpaces may be carefully filled and packed with common rubble work, ſo as to bring the top of the courſe to a level: the blocks compoſing the outſide of each courſe to be ſtraightened and rough jointed with the hammer.

The mortar for this purpoſe to be thus compoſed: for every two buſhels of unſlaked or clod lime, allow one of terras, and three buſhels of coarſe clean ſand, or ditto mixed with fine gravel; a ſufficiency of which mortar being allowed as common backing mortar for common rubble work, it will be worth while to uſe large ſtuff, and bring it a little together by hammer jointing, to ſave the mortar.

The 3100 cube feet of terras work caſed with aiſler, being the whole of the ſolid of the ſhaft of the columns from the above ground ſolid, for four feet in height, which will bring the work above low water; I ſuppoſe the average of two feet breadth from the outſide to be of aiſler, and ſet in terras mortar; viz. to a buſhel of clod lime a buſhel of terras, and a buſhel of clean coarſe ſand, well beaten, and uſed as ſoon as brought to a proper

proper consistence, the interior part of the rubble work in the same mortar as prescribed for the square foundations; so that the use of the internal blocks flatted and bedded as before mentioned, will not only save the backing mortar but render the work stronger.

The rest of the solid of the pillars computed to amount to 627 cube yards, to be built with aisler in the proportion of the last article; only as no terras will be necessary, the terras must be supplied by the addition of an equal quantity of sand, that is, to two bushels of clod lime four bushels of sand.

J. SMEATON.

Austhorpe,
14th *November* 1783.

BRIDGE AT CARLTON FERRY.

Mr. SMEATON's Opinion concerning the building of a Bridge over the River Aire at Carlton Ferry.

HAVING considered two designs for a bridge over the river Aire at Carlton Ferry, one being for a bridge of stone, the other for a bridge of wood upon stone piers, both drawn by Mr. John Carr, Architect, I am of opinion that the design for a wood bridge being no more than 11½ feet head-way above the level of spring tides, will not be sufficient for the passage of vessels under the same in time of freshes; such, as in other respects, allow the river to be in a navigable state: but that the design for a stone bridge, the crown of which arch appears to be intended to be elevated above 21 feet above the level of the spring tides, will be sufficient for the purposes of navigation. But that in case the wood bridge before mentioned, is furnished with draw leaves or falls properly constructed to answer the purposes of navigation, then I see no objection to the said design on account of navigation.

J. SMEATON.

London,
25th *April* 1774.

On Mr. CARR's Design for Carlton Bridge.

THE hindrance that an additional stone bridge of any kind must necessarily be to the navigation, I apprehend has been fully considered by the proprietors of the navigation previous to obtaining the act; and as this bridge will, according to the measures stated thereon, afford a sufficiency of head room for the vessels in all extremes of floods, I do not see any material objection thereto that can be removed. But as the arch will be always more or less of it under water, and as much as possible to prevent damage to the arch and to the vessels by striking, and the masts and ropes by rubbing against it, I would advise

advise that the angle which the face of the arch makes with the soffite, be rounded off by a radius of about one foot, quite round from one springer to the other, on both sides of the bridge.

As a considerable part of the present water-way appears to be interrupted by a solid, it seems worthy of consideration by Mr. Carr, whether a dry arch on each side may not tend to the security of the bridge in giving more ample passage to the water; this matter chiefly relates to the proprietor of the bridge; yet if any thing material should happen to the bridge from the want thereof, the navigation may in consequence suffer interruption.

I. SMEATON.

Austhorpe,
18th *January* 1775.

MONTROSE BRIDGE.

ESTIMATE of a Bridge according to a Sketch proposed for Crossing the South Esk from the Inch Breck to the Fort Hill at Montrose.

	£.	s.	d.	£.	s.	d.
TO masonry in the bridge, extending from the north abutment towards low water mark, upon an extent of 150 feet from high water mark, at the foot of the brae, towards the main channel, from a computation of particulars - - -				1697	0	0
To nine bays of timber scaffolding, at 45 feet each, extending in length 405 feet, from a computation of particulars, at 233l. each bay -				2097	0	0
To the masonry extending from the south end of the said scaffolding to the south shore, if taken at the same price as that in the north (though less work), will be - - -				1697	0	0
				5491	0	0

EXTRA ARTICLES.

	£.	s.	d.	£.	s.	d.
To a great piling engine for driving the large bearing piles -	150	0	0			
To small piling engines, boats, punts, various machines, scaffolding, centers, and utensils - - - -	500	0	0			
To superintendance, suppose for two years - - -	240	0	0			
To incidental and unforeseen expenses - - -	250	0	0			
To expenses in temporary scaffolding, and driving the main bearing and fender piles, being 56 in number, at 3l. each - -	168	0	0			
To the contingence of quarry rubble for the purpose of securing the ground about the foundations, where it may be found necessary in the course of the work - - -	38	0	0	1346	0	0
Total of the bridge				6837	0	0

INCH BRIDGE.

	£.	s.	d.
The bridge over the inch burn being of masonry, and taken at the same expense as the north end of the main bridge, will come to -	1697	0	0
	8534	0	0

N. B.

N. B. In the above eſtimation no roads by way of acceſs, nor any thing is comprehended beyond the termination of the parapets of the wings or retaining walls, no charges of law, intereſt of money, or damage of grounds for laying and working materials, or quarry leave, nor any remuneration to the engineer in chief.

The main walls are ſuppoſed to be of white craig rubble ſtone, built in the beſt manner, in the ſtyle of the fronts of the new ſchools: all the building under high water-mark to be done with mortar proper for the ſalt water: the arches, blocking courſe, and caping, and ſuch quoins and courſes of the foundations as are neceſſary to be hewn, are eſtimated of the beſt Lauriſton ſtone. The timber is all ſuppoſed to be of the beſt Riga or Dantzick fir.

The charge per foot running of the maſonry part is 9l. 14s., that of the ſcaffolding 5l.

TINMOUTH BARRACKS.

To the Honourable Mr. St. John.

Sir, Newcaſtle, 22d January 1780.

Mr. WALTON received your letter of the 28th of December laſt, deſiring our opinion upon certain matters therein mentioned, and accompanying a plan of a parcel of ground part of His Grace the Duke of Northumberland's manor of Tinmouth, upon which barracks have been erected, and alſo a particular and valuation of the ſaid parcel of ground, and the coal ſuppoſed to be under the ſame, propoſed to be given in exchange for ſundry parcels of land, which His Grace holds by leaſe from the crown.

We now beg leave to acquaint you, Mr. Smeaton came to this place on Monday the tenth inſtant, and that we proceeded upon the buſineſs the following day, and wrote to the Duke of Northumberland's principal agent William Charlton Eſq., and to Mr. French, His Grace's bailiff for the manor of Tinmouth, and ſeveral perſons whom we thought proper to have the aſſiſtance of on our view. We had no anſwer from Mr. Charlton, either to our joint letter, or to one Mr. Walton wrote to him upon the fifth inſtant, and Mr. French gave us for anſwer that he had no directions, but notwithſtanding that he would have attended us upon our view, if he had not been under the neceſſity, (as deputy clerk of the peace for the county of Northumberland) to attend the ſeſſions; ſo that we were diſappointed of any aſſiſtance from the Duke of Northumberland's agents.

We proceeded on our view on Wedneſday the twelfth inſtant to the barracks, and made the neceſſary obſervations there, to enable us to ground our opinion upon; and as a new ſurvey of the barracks and ground ſeemed to us neceſſary, an able ſurveyor was immediately ſet to work, not only to make a ſurvey and plan of the ground upon which the barracks are built, but of the buildings alſo, and of the ſeveral high roads, foot paths, &c., which plan you receive herewith; and alſo one laid down by a ſmaller ſcale, taking in Tinmouth Caſtle, Clifford Fort, &c., accompanied by an eſtimate of the yearly value of the lands, ſuppoſing no buildings to have been made, and of the expenſe which it is computed the barracks might at firſt coſt, on the foundation of prices paid in this country for work of a ſimilar nature.

Having

Having fince given this bufinefs all the attention in our power, we fit down to inform you, that we find the ground upon which the barracks are built, with the fpace on the outfide of the buildings, does not amount to more than feven acres and 19 perches, according to the furvey made by Mr. Fryer, and we apprehend the difference of two roods and 25 perches arifes from the wafte of ground by the fliding of the banks into the fea; and that the quantity will continue to diminifh, and the fea in the courfe of years entirely deftroy the buildings on that fide of the fquare of the barracks joining upon the feafhore: under this very material inconvenience, which in our opinion can no way be prevented but at an immoderate expenfe, it becomes very difficult to afcertain what may be the prefent worth of the fee-fimple and inheritance of the faid parcel of ground, with the way-leave or right of paffage over the adjoining lands of the Duke to and from the barracks, propofed to be granted therewith: but having maturely confidered the fubject, we muft obferve, that the value of lands principally depends upon local fituations; and we do not fee a better rule or guide than that which other lands of equal quality in the [illegible] are let for; and as we are well informed His Grace's lands adjoining upon the barracks are let at fifty fhillings per acre, the fame rate at which Mr. Fryer values them, we cannot think the barrack grounds deferve more; fo that the annual value thereof upon the quantity now in being, according to Mr. Fryer's furvey, will amount to feventeen pounds fifteen fhillings, which, at twenty-five years' purchafe, will amount to four hundred and forty-five pounds; but confidering the Duke of Northumberland is under no obligation to fell, and it muft be fuppofed he fells merely for the accommodation of the Crown, and confidering that fuch accommodation breaks into His Grace's eftate, we think the prefent worth of the fee-fimple and inheritance thereof, with the way-leave or right of paffage to and from the barracks propofed to be granted, will deferve thirty years purchafe, amounting to five hundred and thirty-four pounds; His Grace referving to himfelf the fea banks behind the barracks, and granting a liberty at all times to the fervants of the Crown to enter upon and take fuch methods as they fhall think proper for the prefervation of the fame.

The public highway for carriages from Tinmouth to Shields, paffing very near the barracks on the north fide thereof, will be very fufficient to anfwer every purpofe of the barracks, and the foot paths mentioned and defcribed will be very fufficient for every communication between the barracks and Clifford's Fort, as well as the Spanifh Battery.

We have endeavoured to inform ourfelves whether any, and what damages may be done by the foldiers in the adjacent lands, and from thence and our own obfervation, we think that damage (if any) muft be very inconfiderable; and from the commanding officer on

on duty, when we were there upon our view, we were informed not one complaint had been made during the time of his refidence.

It is very clear to us, that it will be attended with no inconvenience to His Majefty's fervice for His Grace the Duke of Northumberland to referve the banks between the barracks and high water mark, as mentioned in the faid particular, there being no appearance of ufe from thofe banks to the Crown, for the purpofe of bringing ftores by fea to the barracks, or for any other purpofe whatever, the banks or cliffs being fo fteep and rugged as to be very difficult of accefs; nor could any veffel be brought to the foot, or lie there with fafety without digging a harbour, and erecting proper piers for defending the veffels laid therein.

In regard to the coal under the faid feven acres and nineteen perches of land, we had that matter under full confideration, and are clearly of opinion, that no calculation of quantity, quality, or value, can be made thereof, upon that fair ground which we think ought to determine the value to a purchafer. Conjecture of feveral feams of valuable coal being within and under the lands before mentioned, cannot juftify us to found a calculation upon; we have defired His Grace the Duke of Northumberland's agents to acquaint us if any borings have been made in the lands of His Grace, at or near Tinmouth, but to this they have given us no anfwer; and as no judgment can be juftly formed without proper trials to be made by boring, we beg leave to be excufed from making any eftimate with refpect to the coal. Our obfervations with refpect to the coal would have ended here, but as we think ourfelves obliged to make fome remarks on the valuation handed to us, we beg leave to ftate the following particulars:—The quantity and value, as fet down by the Duke of Northumberland's agents, cannot be applied to the value of the coal fuppofed to be under the barrack lands, as being founded on what His Grace lately agreed for at Tinmouth Moor, which was then and now is an open working colliery, as no notice is taken of the great expenfe which attended the winning of it, or of laying waggon ways, building fteaths, and other incidental expenfes of bringing the coals to market, together with other common expenfes attending the vend; we therefore repeat, the circumftance of the Duke's agreement at Tinmouth Moor cannot apply itfelf to the value of the coal fuppofed to be under the barrack grounds, which lies unknown, unafcertained, and fubject to the expenfes before mentioned to obtain it. We have faid unknown and unafcertained, for at prefent there is nothing that appears to us to fix the certainty of the exiftence of any valuable feam or feams of coal under thofe lands; there may be feams of coals that may be very valuable, for any thing that we can fay to the contrary, but whether there are fuch or not feems to us problematical. The colliery now working by His

His Grace the Duke of Northumberland on Tinmouth Moor, is at 2¼ miles diſtance, or thereabouts, in a ſtraight line; nor is there any other colliery to our knowledge now worked, according to the neareſt line, nearer than half a mile from the barracks, and the ſeam of coal worked there, according to the general courſe of the riſing of the ſtrata towards the ſea, ſhould be either out of or near the ſurface of the ground at the barracks; but the depth and courſe of ſtrata may be ſo varied, even in the laſt mentioned ſpace of half a mile, by interruptions called dykes, as to leave no more than that kind of probability or proſpect, which may be ſufficient to induce a land owner or an adventurer to be at the expenſe of making a trial of the ground by boring; and after that is aſcertained with favourable circumſtances, yet the expenſe of making an actual winning, ſo as to bring the colliery into actual working, and the clear profit thence ariſing, is in its own nature ſo uncertain, that the undertaking becomes no other than an adventure, which, if really profitable, by far the greateſt part is due to the riſque and hazarded capital of the adventurer, and not to the owner of the ground; ſo that whether the owner himſelf becomes an adventurer, or any other, the land owner's intereſt in the coal is no more than what would be given for the privilege of working it, by the general eſtimation of thoſe who make theſe adventures their object. Having gone thus far, you will excuſe us when we add, that when we know the colliery which is ſuppoſed to be under Tinmouth Barracks is won, and in a working ſtate, with the time in which the coal will be turned into money, we will have no difficulty in giving a valuation of the ſum it is worth to be purchaſed, at any given period. At preſent we have no data to go upon, we have no evidence even of probability from His Grace's agents, and till that kind of evidence is had to reduce the matter to as great a certainty as the nature of the affair will admit of, a doubt muſt remain with us, and conſequently we cannot think it right for His Majeſty's ſervice to purchaſe the ſuppoſed property of coal at any rate whatever. But here it may be aſked, what will become of the barracks, if His Grace the Duke of Northumberland ſhould find the colliery good, and work away the ſame? To this we anſwer, that the working of this colliery ſeems to us to be at a great diſtance in point of time, and that though the working of a colliery will occaſion the ſurface of the ground to fall in irregular hollows, and thereby very greatly damage lofty and maſſy buildings, yet in the preſent caſe, we cannot conſider the barracks as ſubject to the ſame damage, as being low and light buildings, conſiſting of a ground floor only, and in that reſpect, in our conception, much on a footing with cottages and pitmen's houſes, which are commonly erected on the very ground under which a colliery is working, or to be worked; and as often as ſuch damages happen, reparation is made at a ſmall expenſe after the ground is ſettled, and the habitations rendered comfortable again to the occupiers. For theſe reaſons, therefore, with what follows relative to the inſtability of the barracks, from the ſliding banks of the ſea ſhore, we

we have not a doubt but that it will be for His Majeſty's ſervice to run the riſque of any damage which may be ſuſtained by working the colliery under the barrack grounds.

Having finiſhed what relates to the lands upon which the barracks are built, and the colliery which may be under the ſame, we proceed to make our obſervations reſpecting the condition of the barracks themſelves, their ſtability, propriety, and convenience of ſituation.

On this head we muſt obſerve, that though we cannot look upon ourſelves as judges of the propriety of military ſtations or conveniences, yet we muſt neceſſarily take notice, that the banks lying between the barracks and the ſea ſhore, of which His Grace the Duke of Northumberland propoſes to keep poſſeſſion, are of a very conſiderable perpendicular height, and being compoſed wholly of a factitious clay, mixed with ſtones and gravel, and irregularly interſperſed with a ſtratum of ſand, in wet ſeaſons they become ſpringy; and as the ſea waſhes away the foot of the cliffs, the banks gradually ſlide down, and the degree of waſte of the banks may be judged of as follows:—

According to the plan accompanying the particular we received from you, a clear ſpace is deſcribed between the ſouth line of the barracks and the banks, ſufficient to receive the ſouth-eaſt and ſouth-weſt baſtions entire, together with the full breadth of ſeventy-ſix feet in the curtain on the ſouth ſide, agreeably to the reſt. At the time of our view we found a conſiderable part of the ſouth weſt baſtion had ſlid down into the ſea, together with a great part of the original curtain, ſo that in one place the verge of the broken ground was not twenty feet from the ſouth wall of that ſide of the barracks; we have therefore no reaſon to doubt but that in a few years a part of the buildings themſelves will ſlide down the bank, and in time the whole, unleſs ſome effectual method be taken for ſupporting thoſe very irregular inclining banks from the depredations of the ſea. We doubt not but that the original ſtate of the ground was according to the plan; it is however now ſo far changed, that if nothing is done, or the means uſed by the King's ſervants for that purpoſe ſhould prove ineffectual, it becomes, in the next place, a conſideration how far thoſe banks can or ought to be ſupported, which is to be done at the expenſe of the Crown, and conſidering this as a matter relative to the good of His Majeſty's ſervice, we do not conceive, that with reſpect to His Majeſty's more than any private ſervice, any thing is worth more to preſerve than it originally coſt to produce, provided it can be reproduced with the ſame coſt, and to the ſame intent. In this ſtate of the matter, though we do not think it impoſſible to ſecure the banks from further depredations of the ſea, yet if done in an effectual manner, the expenſe would be ſo great that we are very clear it would be far leſs coſt to build

build up the barracks anew as they happen to fail, nay even to build the whole new upon fresh ground, than to secure the banks; and as the soil and site of Tinmouth Castle are not only the property of the Crown, but in our idea proper for the reception of barracks, there cannot, as we judge, be a doubt of its being eligible to remove them to that situation, in case they cannot be continued where they are at a moderate expense.

And now having concluded our observations, and given our opinion on the several points referred to us, we trust what we have done will be satisfactory; we can however say that we have gone through the whole impartially, and with care and attention; but we cannot dismiss the subject without making this general observation, — that though it appears to be improper to purchase the coal supposed to be under the barrack grounds at any rate whatever, yet we think it would be right to purchase the lands, not only to give the Crown a power of enjoying the barracks, during the continuance of their being useful, but to vest an authority in His Majesty to remove the buildings to the castle, or to let the remains stand as shall be thought expedient. This seems to us to be the best method of settling the business on an equitable footing to the parties, as His Grace will have satisfaction for the property he parts with, and that property will be vested so that it may be made such use of as shall be judged best for His Majesty's service.

We are, Sir,

Your most obedient servants,

NICHO^s. WALTON.

J. SMEATON.

P. S. Since forming our ideas and opinions upon which this Letter was written, we have seen Mr. Charleton, but have not received any information from him to induce us to alter the sentiments we have expressed.

To the Honourable John St. John,
Surveyor General of the Crown Lands.

LEEDS INFIRMARY.

TO the Committee of Leeds Infirmary.

Gentlemen,

I HAVE inspected the stone cisterns made at this hospital by the late ——— Craven; I find them nearly of the capacity proposed; but as I understand they never held water from the first, nor do they seem in a capacity of doing so now, or of being made to do so, without taking them all to pieces, and putting them together with the greatest care and firmness, which would of itself be a considerable expense. Each double cistern, when full, is charged with above six tons of water, and relative to this weight they have not only been much too slightly bonded together in their joints with iron, but I apprehend the foundation upon which they have been built has settled under the weight of the whole; for the least settlement or giving in the joints must and will necessarily disunite the cement of whatever kind, and thereby render them leaky. What the nature of the agreement was you best know; if to make them complete to hold water, it was then the undertaker's business to look to the foundation and strength of his bondages: but yet, Gentlemen, if these cisterns can be rendered useful to you, it would seem more eligible so to do, than to return the materials upon the hands of the widow, which, when taken to pieces, will be of little value. I take it for granted you wanted, and still want these cisterns; and had they not been so undertaken to be made of stone, you had ordered them of lead, in which case strong wooden frames of timber would have been wanted to have supported the leaden lining, which frames of timber, though oak, would have been liable to need rebuilding in 20 years, in which case the workmanship upon the lead would have been to renew likewise: had therefore the proposition been how to render these cisterns *durable*, like the rest of the buildings, and which every public building ought to be rendered as much as possible, then you could not have been better advised than to have put together a casing of large stone flags, which the country affords, in order to support the leaden lining, and in this respect these cisterns as they now stand, will completely answer that end; and though in putting them together so as to hold water without such lining, there is work upon them that would have been unnecessary; yet if a reasonable allowance be abated from the first stipulated price for this superfluous work, it will be much less loss to the widow, and much less disadvantageous to

to the truſt than either the removal of the materials, or an attempt to render them water-tight in the manner they are. According to my eſtimate they may be completely lined, as they now ſtand, with lead of 7lb. to the foot, for about or ſomewhat under 30l.; of which about 8l. will be workmanſhip, the other will be the neat value of the lead and ſolder.

According as it has been given in to me, Craven's eſtimate was:

		£.	s.	d.
Stones	- -	14	14	0
Cramps and cement	-	2	5	3
Work	- -	13	2	6
		30	1	9

How far the ſtones were properly valued at 14l. 14s. (carriage, I ſuppoſe, included) I know not, having never had occaſion to purchaſe any of that magnitude. There are in the whole 20 ſtones, ſo that they will come to 14s. 8½d. nearly per ſtone, which on an average contains about 24 feet ſuperficial each; but as the Committee have agreed to take them at that price, on ſuppoſition they were rendered effectual to the purpoſe, ſuppoſe

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Widow Craven paid for the ſtones - -				14	14	0
Cement and cramps -	2	5	3			
Work - -	13	2	6			
	15	7	9			
Half of which is	7	13	10½			
which deducted on account of what would have been ſuperfluous, on ſuppoſition of the ſtone frame being made purpoſely to be lined with lead, then there will remain for cramps, mortar, and work - -				7	13	10½
And there will be payable to Widow Craven -				22	7	10½

which, in my opinion, is a high valuation of the work for the purpoſe above mentioned; and there will be 7l. 13s. 10½d. retained in the hands of the Committee toward the workmanſhip of the lead lining, computed at 8l.; ſo that the truſt will have very little more than the value of the lead and ſolder to pay for, to make the work effectual in the ſame manner as if originally intended for lead ciſterns in ſtone caſings, which, in my opinion, would have been the complete way of doing it; and, at the ſame time, the wooden covers, the

the conveyances for bringing in the water, and conduits for carrying it away will be preſerved, which would be loſt in caſe the work were totally demoliſhed. That this is an equitable way of conſidering the matter appears hence: that if the Widow Craven were to line the ciſtern with lead, ſhe would then undeniably complete the work; and as ſhe would add ſo much real property to the hoſpital as the value of the lead, for this ſhe ought to be allowed in addition to the 30l. 1s. 9d., and ſhe would have to pay 8l. for the work inſtead of allowing 7l. 13s. 9d.

I muſt obſerve, that a couple of reſervoirs capable of holding between 12 and 13 tons of water, which will be filled many times in the year by rains, will not only be a ſafety to the hoſpital, but an acquiſition well worth the expenſe. Rain water is undeniably the beſt for waſhing, and though river water is more eſteemed for brewing, yet it differs from rain water only in being mixed with a ſmall proportion of hard ſpring water, of which kind the infirmary having the command by their well, a proper mixture of the two will anſwer the ſame as river water for brewing, ſo that (in very long droughts excepted) the infirmary will always have a command of water within themſelves; and, as I apprehend, what water will be wanted during ſuch dry ſeaſons to be brought will be reduced to ſo ſmall a quantity, that the carriage had better be paid for than go to the expenſe of any further pump work, reſervoirs, or machinery.

J. SMEATON.

Auſthorpe,
11th *Oct.* 1776.

P. S. As I have mentioned the want of ſtrength of bondages and foundation as the cauſe of the failure of the ciſtern's holding water, it may perhaps be doubted whether they will be ſufficient when lined with lead. But, I muſt obſerve, that if the amount was the thickneſs of a piece of poſt paper, by which the joint was broken, it would be ſufficient to deſtroy the uſe of holding in the water; but if lined with lead, the lead will comply without breaking; ſo that conſidered merely as a caſing to ſupport they are ſufficiently ſtrong.

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EARL OF EGREMONT'S COALS.

THE REPORT of JOHN SMEATON, Engineer, refpecting the Practicability of exporting Coals from the Eftates of Branfty, Birkby, and Afpatria, in the County of Cumberland, belonging to the Right Honourable the Earl of Egremont.

HAVING carefully viewed the fituation of the eftates of Branfty, Birkby, and Afpatria, with refpect to the fea, together with the different propofitions that have been pointed out to me as probable means of carrying and fhipping coals from thence refpectively, I am of opinion as follows; and, firft, refpecting

The Eftate of Branfty.

It feems here perfectly practicable to carry the coals upon a rail road, acrofs Mr. Ellifon's rope-walk from the place where the colliery is expected to be won, to a yard belonging to the faid Branfty eftate, which has been intended for the depofition of timber, or other merchandife, which is not only adjoining to the public ftreet of Whitehaven, near the arch built by Sir James Lowther, but adjoins upon the wafte ground, being the frontage of the fea-fhore immediately behind, or north-eaft of the north pier lately erected as part of, and, as I underftand, the boundary of the port of Whitehaven, as defcribed by act of Parliament: coals therefore being brought from the interior parts of the eftate acrofs the faid rope-walk to the ground contiguous to the fea-fhore, as above defcribed, the queftion is then, Whether it will be more eligible to drop the coals in the yard already defcribed, and from thence cart them through the ftreets of Whitehaven to the harbour, which is within Sir Jame's Lowther's property; or to build a harbour upon the Branfty eftate, contiguous to the faid north pier of the harbour of Whitehaven? The proper refolution of this queftion indeed depends upon a great variety of circumftances; that is to fay,

1ft.

1ft. How far it is practicable that a harbour is capable of being erected and kept open upon the Branfty eftate, fo as to admit of the fafety of veffels; and of what burthen; together with the probable coft of erecting the fame?

2dly, After knowing the probable coft of building a harbour upon the Branfty eftate, then comparing the intereft of the fum that is likely to be funk in effecting this work, with the price of the cartage of coals from the faid ground upon the annual vend of coals, that is to be expected to be fhipped from the faid eftate, the difference will appear.

3dly, On fuppofition, that on this comparifon it fhould appear that the more eligible method is by cartage to the prefent harbour, it will be a further confideration how far, according to the acts of Parliament now in being relative to the harbour of Whitehaven, My Lord Egremont can entitle himfelf to, and infure himfelf of thofe advantages, in difpofing, birthing, and laying on fhips, for the reception of His Lordfhip's coals, that the nature of the place in its prefent ftate admits of.

4thly, Whether on fuppofition of the preceding enquiry turning out favourable to His Lordfhip's views, he will have power of compelling that the ftreet of Whitehaven through which the coals would be carted, fhould be kept in their prefent ftate of repair, on fuppofition that Sir James Lowther fhould think proper to ceafe his cartage through the fame avenues?

As an engineer, the firft article, comprehending the practicability and expenfe of erecting a harbour upon the Branfty eftate, is the only part of the propofition that properly comes before me, and as this is a neceffary foundation for making the other comparifons, to this I fhall at prefent confine myfelf, leaving the other difcuffions to be determined where they more properly may, by the gentlemen already employed as coal viewers, to advife upon the winning of the faid collieries, and His Lordfhip's agents in the country.

The north pier of Whitehaven, which has been erected within thefe few years paft as a boundary to the port, appears to me as an unfinifhed part of a larger and more extenfive defign; but what this defign is, or has been, I had not an opportunity of getting any certain intelligence. From the place of commencement and direction in which it is carried out, it would feem to me, as if Sir James Lowther does intend, or

has

has intended, to carry forwards his coals over his archway, and to have shipped from this pier those of his coals that are now carted from the said archway to the quays; were this done, and My Lord Egremont supposed to have an equal right to do the same, his purpose would thereby in whole, or in part, be also served; at present it does not seem sufficiently carried forwards to serve the purpose of either: but taking it as it is, it appears to me to be a very sufficient defence or break-water, so far as it is gone to the south west side of the harbour, that I would propose for Bransty, and which will therefore serve the same purpose to the Bransty harbour as if it had been built with that intent, except what relates to the right of laying of railways, and leading the Bransty coals thereupon, of which point I am uncertain, but of which it would behove My Lord to be fully advised, in case that, upon the whole, a harbour at Bransty is deemed the most eligible.

The actual laying out a harbour requires a more minute consideration than the time I was at Whitehaven would admit; it is sufficient to say, that it appears to me, that a harbour may be made, by running out a pier upon the Bransty estate, from or near to the north west termination of the present north pier of Whitehaven, so as to skreen about half a dozen ships at a time from the violence of the south west or western seas, and when any greater number should arrive or be wanted, they can always lie in the port of Whitehaven, either till they can sail after being loaded; or after arrival till a proper birth can be had within the Bransty pier.

I observe that the north pier is carried out from the shore about 160 yards, and extends into eight feet water at a neap tide, which from the flow of the tides on this coast, should make from 14 to 15 feet water at the high water of a spring tide; and which, I apprehend, is as much, or nearly as much, as is generally maintained at the coal quay in the interior part of Whitehaven harbour; and I am of opinion, that by running out a pier upon the Bransty estate of about 120 yards in length, in a proper direction and construction, as much water may be maintained within the same as at the present termination of the north pier.

For this work there can scarcely be a quarry more commodious than that at Jack-a-dandy Hill, or point within the Bransty estate, that is now wrought for supplying the piers of Whitehaven with stone. Having, therefore, attentively considered the situation of the quarry and the work, and having made a careful estimate of the expense of building

ing 160 yards running of pier, in this situation it will, according to my estimate, cost 3059l., say 3100l.

Now, if upon the comparisons above mentioned, it shall appear eligible to go into this expense, then I would advise this work to be undertaken, and for which I shall be ready to enter more minutely into the detail, and produce the proper working plans: but if not, I cannot advise it to be attempted. The above expense is, however, independent of the laying of waggon ways from the shore, and the making of proper spouts, or hurrys, as they are there called, for putting the coals into the vessels, which may propably swell the above estimate to 4000l. I would not, however, be understood that the building 160 yards of pier, as above stated, will make the very best harbour that can be made upon the place; what I mean is, that it will be sufficient to begin with, and to see how things are likely to answer; and if so, it may be afterwards extended either in length, or by building a counter pier on the north side of Bransty harbour similar to the north pier, now in part made as above mentioned, for Whitehaven; the one or the other to be proceeded with as experience shall direct or shew necessary, after the work first proposed to be erected is put to a full trial. I further looked upon it, that the outworks that have been erected to break off the violence of the south western storms from the harbour of Whitehaven, will be almost of the same advantage to the harbour of Bransty, so that this harbour would answer its end much more advantageously than if the works at Whitehaven had never been erected.

2dly, Respecting the Birkby Estate.

It has been pointed out to me, that by way-leaves through the estate of Mr. Senhouse, the coals of Birkby can be carried to the harbour of Maryport, at the mouth of the river Ellen, and there shipped: upon this proposition the opinion of an engineer is unnecessary; but it is further suggested, that as the estate of Aspatria as well as Birkby is so circumstanced, that this river if made navigable, will be equally useful in carrying down the coals thereof to the harbour of Maryport, and it will also carry the coals arising out of several other estates lying upon the said river; with this idea I have viewed the course of the river Ellen, from a point within the manor of Atterby, where a canal has been proposed to be taken off to go through Aspatria towards the sea, at a place called the Blue Dials; from this point to the harbour of Maryport, according to the course of the river's valley, is full five miles, and as by a level taken by Mr. Johnson, from the said

ſaid point of the river Ellen, in the manor of Atterby, to the ſea at the Blue Dial, there is a fall of 60 feet, we muſt account the ſame deſcent in the courſe of the river Ellen, from the ſaid point to the ſea at Maryport.

From the ſaid point, taken above the head of the aqueduct of Atterby mill, for about a mile downward, the ground lies very well for a canal out of the bed of the river, but then the valley begins to grow confined, and the borders of the high ground to lie very ſteep, and grows very embarraſſed about the corn mill of Roſe Gill, which is a new erected corn mill belonging to Henry Fletcher, Eſquire, and ſeems to have been built at a very conſiderable expenſe; from thence downward the river runs very rapid, and in general in a very ſhallow and narrow bed for about 2½ miles, till we are almoſt through the Birkby eſtate; and the bottom of the valley in this ſpace is ſo narrow, the borders in many places perpendicular rocks, and almoſt every where ſo ſteep and embarraſſed that it would be almoſt impracticable to make the navigation otherwiſe than in the bed of the river. Below Birkby the valley is more open through the eſtate of Mr. Senhouſe, yet not without embarraſſments, ariſing from the houſe, and gardens, and mills belonging to this gentleman, and from the aqueduct leading through the ſame to the iron furnace at Maryport: in ſhort, conſidering the number of locks that muſt neceſſarily be required in a fall of 60 feet, the great rapidity and quantity of water in time of floods, the diſcharge of which muſt in many places be provided for, I cannot lay the expenſe of making the ſame navigable through the above diſtrict at leſs than 3000l. per mile, that is, for five miles 15,000l., and this excluſive of any compenſations to the mills and iron works above mentioned, for loſs of water; or to two other mills, though ſeemingly of much leſs account; that is, the mill of Atterby and Sir James Lowther's mill, in the lordſhip of Dereham; for the river Ellen in dry ſeaſons would not be capable of ſupplying the mills, as well as the navigation, if carried on to any great extent.

Were this river made navigable it would, beſides the manors of Birkby and Aſpatria, belonging to Lord Egremont, be the means of bringing to market the coals of Mr. Senhouſe, as alſo thoſe of the manors of Dereham and Croſby, belonging to Sir James Lowther and ſeveral others; and were the ſeveral proprietors of theſe lordſhips deſirous, aiding, and aſſiſting in bringing the thing to bear, ſo that there might be no difficulties to remove but thoſe that ariſe out of the nature of the ſubject, then it would be a propoſition well worthy of attention; but if to the natural expenſe attending the execution of it, as above mentioned, be added thoſe extra expenſes that would attend it, were it to be proſecuted by Lord Egremont upon an adverſe principle with reſpect to the other adjoining

adjoining lords; if carried at all, I am very clearly of opinion the amount would be ſuch as by no means to become an object to Lord Egremont to drive through ſolely. If this then is the caſe, it will therefore remain, that ſhould a ſea ſale colliery be won in Birkby, the coals muſt go to Maryport by way-leaves, through the eſtate of Mr. Senhouſe, who, if he would not grant way-leaves, would, it muſt be imagined, oppoſe a navigation alſo.

It now remains that I give my opinion with reſpect to

The Eſtate of Aſpatria.

Excluſive of the river Ellen, what has been propoſed for the ſhipping of coals from hence, is to take a canal out of the river Ellen, at ſome convenient point above the dam-head of Atterby mill, and carrying the canal for about a mile upon a dead level, there to terminate the ſame, and then to deſcend by a waggon way the 60 feet that the ſaid point of the river has been found to be above the ſea, which occurs in about the ſpace of ¾ of a mile more, to a place on the ſea ſhore in the bottom of Atterby bay, called the Blue Dial. To any part of this propoſition I ſee no *natural* difficulty; the whole queſtion as to execution, ſeems to reſt upon the procuring of way-leave or licence to make that part of the canal that lies out of the lordſhip of Aſpatria, and the expenſe of building an harbour at Blue Dial.

In point of original eſtimation, I would, however, adviſe that the eſtimate of the expenſes attending the winning of the colliery, be made upon the ſuppoſition of a waggon way altogether, from the propoſed place of winning to the Blue Dial, without any canal at all.

Firſt, becauſe in order to procure water from the river Ellen, it will be neceſſary to cut through a property that lies between Aſpatria and the river Ellen, as well as through a property that lies between Aſpatria and the ſea, whereas, if the whole is done by a waggon way, the difficulty of procuring way leave will be confined to one property only.

2dly, Though an ingenious idea of the ready ſhipping and unſhipping of the waggons, containing their loading, from the canal to the waggon ways, and vice verſâ, was communicated

municated to me by Mr. Johnſon, yet it is no ways clear to me, that in ſo ſhort a length of navigation any thing will be ſaved; whereas, if upon the whole the colliery is likely to bear the expenſe of winning by a waggon way, and the building of a harbour at Blue Dial, if it ſhall, after the thing is reſolved upon, be found upon entering into a minute detail of the particulars both ways, that any thing can be ſaved by the execution of a canal, then, by that ſaving, the thing will turn out juſt ſo much the better: the main point, therefore, that ſeems to reſt upon my opinion, as an engineer, reſpecting Aſpatria, is the practicability and expenſe of erecting a harbour at the Blue Dial.

The principal diſadvantage of this place, as to the making of a harbour, is, that as the ſhore is flat, a pier muſt be run out to a conſiderable length before a ſufficiency of depth of water can be obtained. Another diſadvantage is, that here is no outlet of any river or burn to keep the ſame clean, which laſt is indeed a diſadvantage common with Whitehaven, but then the ſand which is driven coaſtwiſe, and a good deal affects the harbour of Whitehaven as well as Maryport, ſeems there a good deal diſperſed, or driven further out to ſea; on the other hand, as the ſeas here are narrow, no conſiderable ſwell can come from the northern or north eaſtern points, nor indeed in the bottom of Atterby bay, where the Blue Dial is ſituated, do there from the appearance of the ſhore ſeem to be very raging ſeas at any time, ſo that a ſingle pier, with the turn of an elbow, to ſcreen off the ſouth weſterly, weſterly, and north weſterly winds, will, as I think, be ſufficient; and being of a proper conſtruction, I apprehend will not be liable to choak up with ſand in any obnoxious degree; ſo that by running out a pier of 300 yards in length, I apprehend that 14 feet water may be gained in ſpring tides, with a ſafe birth for four or five ſhips, and ſeveral more of ſmaller ſize; this is much about the ſame depth of water as at Maryport, and as, like Maryport, the flow of the neap tides is conſiderably leſs than the ſpring tides, no veſſel of any conſequence will be able to ſtir at neap tides, and which indeed is a good deal the caſe at Whitehaven: above a week in each ſpring tide time, there may be expected from 10 to 11 feet water, and upwards, ſo that veſſels not exceeding that draft of water may move every tide, when wind and weather admit, and for ſix or ſeven days, about the neap tide time, veſſels under 10 feet water only can move; the dead of neap making only about ſeven feet, which laſt will yet float veſſels of about 50 tons burthen, or about 75 Cumberland tons of coals.

N. B. The largeſt veſſels belonging to Maryport are ſaid to carry about 300 Cumberland tons of coals, that is, they are veſſels of about 200 tons burthen, which kind of veſſels generally draw about 11 feet water.

 Having

Having carefully computed the expenſe of erecting a harbour at Blue Dial, from an excellent free ſtone quarry at the diſtance of about $\frac{3}{4}$ of a mile; the eſtimate thereof I make to be 5700l.

From thoſe general data, the expediency of the ſeveral propoſitions may be judged of, and the execution of ſuch as ſhall appear advantageous determined; and when that is done, it will then be proper to review the premiſes, and to enter more minutely into the detail thereof than this general view, which was comprehended in two days only, would enable me to do.

J. SMEATON.

Auſthorpe,
19th *October* 1775.

ROSEVEERN AND OWERS LIGHTHOUSES.

To the Mafter, Wardens, and Affiftants of the Honourable Corporation of Trinity Houfe, Deptford Stroud.

My Lords and Gentlemen,

HAVING at your defire, under the conduct of Captain Bromfield, of your brotherhood, furveyed the ifland of Rofeveern, one of the iflands of Scilly, and alfo the Owers Rock off Selfea, in the county of Suffex, with refpect to the building a lighthoufe on each of thefe fituations, I beg leave to report feparately my opinion on both of them refpectively; and firft,

Concerning the Ifland of Rofeveern.

We vifited this ifland the 14th of June laft, during the time of fpring tides. The day being perfectly fine, we landed from a boat without the leaft difficulty. The whole of the rock compofing this ifland appears to be granite, which, on trial with a pick, I found to be fufficiently workable. The ifland is of an oval fhape, and nearly a flat upon the top. Its length is pretty near eaft and weft, and it gently rifes towards the weft end, where it is terminated with large granite rocks, naturally piled on each other, higher than any other part. The length of the flat part of the ifland, including the gentle rife, I meafured to 315 feet; and the breadth 132 feet. Without this flat area, the furface declines faft towards the water; and the whole border is compofed of large roundifh granite rocks, difpofed in a floping form, down to low water, and under it.

The flat area is about feven yards above the half tide-mark, and is about four yards above high water-mark of fpring tides. The high rocks at the weft end form a kind of breafting; the fummit whereof rifes near upon 30 feet above the flat area; fo that I apprehend the floping figure, together with the rough breafting defcribed, fo far curbs the fury of the weftern ftorms that they never break bodily over the flat of the ifland, which I alfo infer from this circumftance, that the whole of the flat is covered with a fpecies of foft woolly mofs, that, as I apprehend, will not grow where the fea wafhes very frequently over,

over, nor does it appear to be attached to the rock fufficiently firm to prevent its being wafhed away and diffipated, if a heavy fea were frequently to fall upon it: however, I judge from the formation of thefe rocks, that in time of ftorms a heavy fpray goes over the whole, and which is alfo corroborated by there being no grafs growing upon them.

From this defcription it would clearly be no difficult matter to erect a lighthoufe upon this ifland, of any height required, if it were eafy to land and unload heavy materials upon it; but as there is no cove or upright breaft of rocks fo as to afford either fhelter or a fufficiency of water for the veffels to keep afloat long together at any time of tide, it is evident that the ifland can be acceffible to veffels of any fize whatever, only in times of the fmootheft water. It therefore appears to me, that a fufficiency of time upon the ifland cannot be got within a moderate number of feafons, without making an eftablifhment upon it; wherein a competent number of workmen and an overfeer could be lodged, and victualled with fecurity, during the fummer feafon. And for this purpofe, upon the flat area I have defcribed, there is a fufficiency of room not only for placing the lighthoufe but for the erection of cabins for fheltering the workmen, and for ftores, and cooking their victuals. And as the whole ifland confifts of granite rock, as already mentioned, the principal part of the ftone materials will be found upon the ifland itfelf, or its near neighbour, which is alfo of granite, and can with a fmall boat be readily vifited therefrom.

As a lighthoufe may be placed upon this ifland without being fubject to the ftroke of the fea, its conftruction will not need to be of that degree of firmnefs as if it were expofed to the waves. It therefore may be built fufficiently compact with rubble, or unformed ftone, efpecially if cafed with aifler of fo moderate a fize as to be readily landed, and which may be wrought with granite or moorftone of the beft quality in Cornwall, which, from what I have experienced, is from the parifh of Conftantin near Falmouth; the cement that I have ufed on former occafions, being of fo compact a nature as to unite the whole building into one mafs of rock; here being time intervening betwixt the ftorms for the cement to harden before it is attacked by the wafh of the fea.

It may be proper, as a matter on which the whole depends, to fuggeft the manner in which I would propofe to erect the temporary cabins for the lodgment of the workmen. Thofe I would conftruct wholly of wood, to be made and fitted together at a convenient harbour on fhore; and being carried in veffels at a proper opportunity a fufficient number of them can be landed and fet up in a few tides to contain as many workmen as can go on with the erection and completion of the reft. I would propofe to make them

them all of fir plank framed croſs and croſs, ſo as to compoſe ſo many large boxes or cheſts, when ſcrewed together. I would ſuppoſe them about 10 feet ſquare area, and ſeven or eight feet high; each cabin to have one bed to hold two perſons. Two of theſe to be appropriated to the kitchen and its conveniencies; one having a fire-place of brick, and four more for ſtorehouſes, and the overſeer. The whole to be joined together, ſo as to form a ſtreet, or narrow lane; the doors and windows to be all next the ſtreet and facing each other. I ſuppoſe about 12 of theſe cabins will be ſufficient. The whole muſt be water tight, every where except the doors, and theſe as light as poſſible, with air holes to be uſed at pleaſure.

I ſuppoſe what I have ſaid will enable the honorable corporation to judge of the practicability of the ſcheme: when the expediency thereof is determined upon, it will then be in courſe to make out the working deſigns; but as very much will depend upon contingence, no draughts that can be made will enable me to form an eſtimate on proper grounds. However, from the beſt view I can make of the ſubject, I cannot judge that this work ſhould be commenced upon a leſs capital than 6000l., excluſive of the furniture and machinery required for exhibiting a light therein.

Concerning the Erection of a Lighthouſe upon the Owers.

The Owers appears to be a hard ſunken rock, of conſiderable extent in the eaſt and weſt direction; the ſhalloweſt water being near the eaſt end, whence it very gently and gradually deepens towards the weſt.

On Saturday the 26th of June, we rowed in a boat from the floating light; and upon the eaſtern part had ſoundings upon an extenſive ſurface at ſeven feet, and much more regular than could have been expected. In ſome places, more towards the eaſtern end, we had ſix feet and under; but thoſe places ſeemed more irregular. The wind was freſh at weſt, and obliged us to depart rather before the computed time of low water: and as this was the day of full moon, and conſequently the ſpring ebbs to be expected ſomewhat lower, we determined to take another trial, if thoſe ſprings offered it: and the next day,

Sunday the 27th June, proving very fine, the wind moderate and at N. W. we took another trial, and in a ſix-oared row-boat went directly over the rock. We had pretty extenſive ſoundings at ſix feet, ſome places $5\frac{1}{2}$, and ſome of 5 feet; but the ſhalloweſt ground ſeemed the moſt irregular. I don't look upon any of theſe ſoundings to have been

been made at ſo low an ebb as ſometimes happens, ſo that I have no doubt of the truth of what has been reported to us, that a perſon has ſtood upon the bottom in a pair of fiſherman's boots; but as theſe times can happen but ſeldom, I muſt lay it down, that a middling ſpring ebb does not give a leſs depth than ſix feet water; and that to allow ſufficient time for buſineſs, we muſt ſuppoſe the foundation to be laid in ſeven feet water at the leaſt. The breadth of the rock in a north and ſouth direction could not well be aſcertained for want of fixed marks; but ſuppoſe it where we took our ſoundings to be 100 yards. It ſeems ſomewhat narrower near the eaſtern end, where the leaſt ſoundings are, but there is not a doubt but that there is an ample ſufficiency of room for the baſe of any lighthouſe building.

In time of great ſtorms the ſhallowneſs of the water will undoubtedly occaſion a great ſurf to break upon theſe rocks at ſome time of tide; in conſequence, I cannot apprehend that ſtones of any magnitude that it is practicable to bring and depoſit here, will lie quietly without being ſubject to be removed, unleſs they are firmly detained in their places. I look upon it as practicable to bring hither and retain ſuch ſtones as may be expected to lie; and conſequently, ſtone after ſtone being laid and others upon them, till a regular platform of ſtone can be formed of regular maſonry, above common low water-mark, the building can then be proceeded with upon principles and in methods that have already been put in practice.

There will however occur great natural difficulties to the proceeding with this work, eſpecially in its early ſtages. Here is too much water at all times to ſee to do the buſineſs in any current method, and here is too little water to float veſſels of any burthen, to bring and deliver their materials in ſize and in quantity: for as they muſt neceſſarily be of a flat conſtruction, and muſt not thump the bottom in a troubled ſea, the tonnage of ſtone that can be expected to be carried out in one cargo cannot be any great matter.

The diſtance of the Owers from the land, ſuppoſed to be at leaſt eight miles, and without any good harbour or quay to retreat to, muſt conſiderably add to the difficulty: and the many fruitleſs voyages that muſt neceſſarily occur in purſuing a work in which nothing can be attempted but in the calmeſt weather, will inevitably render the eſtabliſhment of a foundation (till it is got above low water) both tedious and expenſive. However, to ſhew that it is a work within the bounds of practicability, I will now take the liberty briefly to ſuggeſt to this honourable Board the method in which I would propoſe to proceed.

Beſides

Besides constructing proper vessels, I would, in the first place, construct a diving bell, or rather diving chest, such as was made use of about two years since at Ramsgate harbour, by means whereof large stones that interrupted the clearing a foundation, were got up in 12 feet water, and which it was found practicable to use at a much greater depth had it been necessary. With this apparatus it is very practicable to drill holes in the rock; and, in the first place, to establish a center pin which may be afterwards found, by putting a small buoy upon it; and to which the craft may be occasionally moored while employed there. At a competent distance from this center it is equally practicable to drill any number of holes at pleasure, so as to form a circle, as regular as it could be done upon the plain ground, into which strong iron spindles or pins, being driven to stand up (suppose a foot) above the surface of the rock; large stones of six or eight tons let down within this circular area will be detained from slipping without it till the outward circle of pins is filled with stones of this size, which may be roughly hewn, but so as somewhat nearly to fit each other; lastly, the internal area within the circle of stones, being chocked in with large rough blocks, put down promiscuously, will establish a basement course, that, as I apprehend, will sustain a winter's storm, without material derangement.

The upper side of the stones of the outward circle can in their formation have such indentures cut in them, as shall retain in their places another circle of stones laid upon them, on the same principle as the first course is retained by the iron pins. The interior part of this course being also chocked in with rough blocks, these two courses, which may bring the work a foot above low water, and can be further steadied and bonded with iron cramps, I expect will prove sufficient to sustain another winter.

In this situation the work may be brought to a level, the interstices rammed full, and prepared for laying on a cap course in water mortar, begun solid from the middle, and dove-tailed together in the same manner as the Edystone lighthouse is. This solid course being all united as one stone, will, both by its weight and connection, firmly bond together the whole of the under courses, so that nothing can get out of place, though the iron spindles, or steady pins, were entirely to waste and decay with rust.

After this is done a superstructure may be raised upon this compound base on the same principles, and in a similar manner with that of the Edystone.

A work

A work of this kind is still less a subject of computation, in regard to expense, than that proposed at Roseveern. It will, indeed, very much depend upon good or bad luck of reasons and circumstances; but I think it ought not to be begun upon a less capital than 20,000l.

I remain with the utmost respect
to this Honourable Corporation,
their most obliged servant,
J. SMEATON.

Grays Inn,
22d *July* 1790.

COAL

COAL MEASURES.

AN ACCOUNT of the Meafures of Coals at Newcaftle and London, and of the cuftomary Meafures in the Parifh of Whitkirk, and the adjacent Parifhes.

THE Newcaftle chaldron, by which coals are delivered to the fhips, is fixed by act of Parliament to be 53 hundred weight; and by the ftated proportions ufed at the cuftom-houfe, &c., eight chaldrons Newcaftle, are to make out 15 chaldrons London meafure: the weight of the London chaldron will therefore be 28 cwt. 1 qr. 2 lbs.; and the vats by which coals are meafured at London by upheaped meafure, are, or fhould be contrived, of fuch dimenfions as to anfwer the above quantity.

The bufinefs of Newcaftle in the coal way, not only in regard to the delivery of coals for home confumption but for the collieries, is not done by weight but by meafure; the foundation whereof is the coal bowl, which confifts of 36 corn gallons Winchefter meafure ftriked; a veffel therefore of the capacity of 36 corn gallons corn meafure, contains the meafure of a coal bowl, and the coals are meafured therein by filling them level with the top.

The fpecific gravity of clean coals (that is, when free from ftony or braffy matter, which is heavier) does not greatly differ; fo that at a medium it is found and computed that 21 bowls will make a chaldron of 53 cwt., and hence it will follow that the coal bowl will be 276 lbs. neat weight, that is, 2 cwt. 1 qr. 24 lbs., and each of thefe bowls is a fodder, which is looked upon to be a full load for a two-horfe cart, and a fodder is in general eftimation looked upon to be two-thirds of a good three-horfe cart load (which is not however the mode of carriage of that country, they generally carrying by fodders); 12 bowls will therefore weigh 29 cwt. 2 qrs. 8 lbs., exceeding the London chaldron by 1 cwt. 1 qr. 6 lbs.

Mr. Smeaton has remembered the collieries of Whitkirk parifh and the neighbourhood above 45 years; he always underftood, that when the owners of a colliery had a mind to recommend their coals to fale, they did it by giving good meafure; that is, by giving fomewhat more than the ufual quantity by making their corves larger, or upheaping them

them as much as poffible, and when eftablifhed, and having a greater fale than they could readily fupply, they then were apt to fhorten their meafure; that is, to make the corves lefs or upheap them lefs than ufual. Mr. Smeaton never heard nor could learn any ftated dimenfions for a corf; but he always underftood that a corf of coals was, or ought to be a good horfe load: fo that in winter when the roads were but indifferent, the neighbouring farmers feldom carried above 10 corves at once, and fometimes not fo much. In Mr. Smeaton's memory coals, as well as all other goods, were in a much greater proportion carried upon horfes' backs than they have been within the courfe of the laft 20 years. The ftated weight of a horfe pack is 18 ftone, that is, (eight ftone to the hundred) equal to 2 cwt. 1 qr., and this being underftood to be the weight of a corf of coals, a dozen at this rate will weigh 27 cwt., that is, 1 cwt. 1 qr. 2lbs. lefs than the London chaldron; and in confirmation that the corf of coals is not lefs than the horfe pack weight, about eight years fince, Mr. Smeaton being upon fome experiments on the fubject, weighed fix corves of coals, brought home in his own cart from Walton, which were not quite but yet not much fhort of half the weight of a London chaldron, which made him conclude at that time, that the Halton dozen, and the London chaldron, were nearly the fame thing.

From the near coincidence of the dozen of coals confifting of 12 horfe pack weight, the London chaldron, and 12 Newcaftle coal bowls, he is inclined to think they have all originated from the fame thing; videlicet, the coal bowl of Newcaftle, which itfelf has been adapted to the weight they found it practicable to carry on horfes' backs, there being few, if any, wheel carriages in England at that time; and therefore before the invention of the Newcaftle rail or waggon roads, all the coals that were carried down to the fhips muft have been conveyed on horfes' backs, and though the whole coal trade of that country muft have been only a trifle in proportion to modern times, yet the whole of the trade being carried in this way, it muft have been very confiderable as applicable to horfe labour; we may therefore well expect, that in contracting for the carriage of coals to the fhipping, it muft have been of great confequence in thofe times to have the quantity afcertained that each horfe could and was expected to carry. Accordingly the bowl for wheat, and other grain, in that country being moft generally 4 Winchefter bufhels of eight corn gallons each, that is, 32 gallons; it has been found on repeated trials that a horfe was capable of carrying fomewhat more than this bowl of coals, and therefore that inftead of carrying four eight-gallon bufhels, it has been univerfally agreed that it fhould confift of nine gallons, and in confequence the coal bowl of 36 gallons, has ever fince proved an invariable meafure at Newcaftle.

He

He is further inclined to think that originally they ſent away three fodders, or 24 bowls, to London for a Newcaſtle chaldron (as it ſtill continues for home conſumption), which at London was ſold for two chaldrons, of 12 bowls each; but that as the demand for coals increaſed, they gradually ſhortened their meaſure both at Newcaſtle and London, and this abuſe and uncertainty increaſing called for the interpoſition of the legiſlature, when, having after a courſe of years forgot the grounds upon which this trade had originally commenced, they ſettled it as well as they could to what they found a medium at that time, ordering the Newcaſtle chaldron, not to be a meaſure, but a weight of 53 cwt.

He has never heard it doubted but that the firſt collieries in England were opened at Newcaſtle, from whence they would naturally ſeek inſtruction in opening and working collieries in other parts of the kingdom, and finding that a bowl of coals was drawn at a time, which then would be moſt convenient, as being a proper meaſure for putting upon a horſe, the imitators would naturally do the ſame thing for the ſame reaſon; and as in the manufacturing part of the Weſt Riding of Yorkſhire, the neceſſity of a conſiderable quantity of horſe carriage would ſubſiſt as far back as the firſt getting of coals at Newcaſtle (ſome time, if he recollects his information right, after the year 1200), the load of coals and the horſe pack would eaſily be ſubſtituted for one another; and indeed without ſuppoſing the dimenſions of a bowl corf to be brought from Newcaſtle, the reaſon of the thing, that is, the natural ability of horſes to carry burthens, would bring the matter ſomewhat near, there being only 24 lbs. difference between the pack weight of the Weſt Riding, and the coal bowl of Newcaſtle, the latter being as before ſtated 24 lbs. heavier.

Since the invention of the coal waggon roads and other carriages, as well as powerful machines, or gins for drawing coals from great depths, it has been found convenient to draw more than a bowl at once, and it is now in common practice to draw a 20-peck corf, that is, $2\frac{1}{2}$ bowls at a time, $\frac{1}{8}$ of a coal bowl being denominated a coal peck; and ſince the laying of waggon ways in Yorkſhire (the firſt of which is in Mr. Smeaton's memory), to carry coals to the navigable rivers, they have delivered as many as they can carry in a waggon for a dozen, or chaldron, now amounting to about from 40 to 45 cwt., taking pay for the coals in proportion; but firſt calculated with intent to avoid the payment of the river's toll, which uſed to be taken by the chaldron or dozen before the laſt act of Parliament.

J. SMEATON.

Auſthorpe,
27th *January* 1779.

N. B.

N. B. The act now paſſing for Mr. Brandling ſerving the town of Leeds will, as by agreement, probably fix the weight or meaſure of the chaldron or dozen at Leeds; but Mr. S. has not yet heard what it is.

To Lady Irwin.

Mr. Smeaton preſents his moſt reſpectful compliments to Lady Irwin, and incloſed herewith begs leave to preſent her with the beſt account he is able to give of the weights and meaſures uſed in the coal trade, ſo far as they have come to his knowledge.

Auſthorpe,
27th *January* 1779.

From Lady Irwin.

Lady Irwin is more obliged to Mr. Smeaton for the paper than ſhe can expreſs, and can't, without being infinitely aſhamed, reflect upon the trouble ſo very juſt a ſtate of an intricate and difficult buſineſs muſt have given him; begs leave to return him her moſt grateful thanks, accompanied by every good wiſh for himſelf and family.

Wedneſday Evening.

POZZELANA

POZZELANA MORTAR.

DIRECTIONS for preparing, making, and uſing Pozzelana Mortar, by JOHN SMEATON, Engineer.

THE firſt thing that ſhould be done, is to ſift it through a coarſe wire ſieve, ſeparating what will paſs through the ſieve from what will not, and then to ſift what has paſſed through the firſt ſieve through one of a finer ſort. A wire ſieve having about 7 or 8 maſhes per inch running, will be of ſufficient fineneſs, and all that will paſs the ſecond ſieve will be fit for uſe, what will not paſs the ſecond ſieve muſt be reſerved for grinding, and what would not paſs the firſt ſieve muſt be broken to a ſize conformable to what would not paſs the ſecond, and then all ground together; but in breaking the large that would not paſs the firſt ſieve, it will be proper to pick out a kind of grey ſtony matter, as well as other heterogeneous ſubſtances that get accidentally mixed therewith; and which will readily diſcover themſelves from the true pozzelana, and which have no cementing quality, and render it more difficult to grind. The true pozzelana is of a dark brown or dirty red colour, and the larger pieces being broken will readily diſcover themſelves, eſpecially with an ordinary magnifying glaſs, to be of a ſpongy ſubſtance with innumerable little cavities like a cinder, and not much harder.

That part of it requiring grinding muſt firſt be got perfectly dry, either by the ſun or by a drying kiln, otherwiſe it is apt to clog the mill ſtones, and it is done by far the moſt completely by grinding it upon a pair of corn mill ſtones, which will at one operation reduce it to a proper fineneſs without need of further ſifting; French ſtones anſwer the purpoſe beſt, for though it may be done by other kinds of mill ſtones, yet being mixed with flinty matter, which cannot readily be picked out, no other kind of ſtones will ſtand the ſervice, if wanted in any conſiderable quantity. The millers however are not very deſirous of meddling with it, on account of its ſpoiling the colour of their ſtones. I have therefore in the larger kind of works that I have been concerned in, found it worth while to conſtruct a mill on purpoſe, to go by water, wind, or horſe, according to convenience.

In making mortar of it, it muſt be mixed with lime in much the ſame manner and proportion that terras mortar is made; it muſt be obſerved that the better and ſtronger the lime is, the better and ſtronger the cement will be, but like terras it may be uſed with any

any lime, and in making comparative trials with terras, the ſame ſort of lime ſhould be uſed with both.

The beſt kind of lime for water works that I know of, is from Watchet in Somerſetſhire, Aberthaw in South Wales, and Barrow in Leiceſterſhire, and the ſtrongeſt compoſition I know is made by an equal quantity of lime, ſtriked meaſure in the dry powder, after being ſlaked and ſifted, and of pozzelana ground and prepared as above, and if put together with as little water as may be, and beaten till it comes to a tough conſiſtence like paſte, it then may be immediately uſed; but if ſuffered to ſet, and it be afterwards beaten up a ſecond time to a conſiderable degree of toughneſs as before, uſing a little moiſture, if neceſſary, it will ſet harder but not ſo quick.

This compoſition is of excellent uſe in jointing the ſtones that form the lodgement for the heels of dock gates and ſluices, with their threſholds, &c. when of ſtone.

A ſecond kind of mortar is made by uſing the ſame proportion of ingredients as terras mortar, that is, two meaſures of lime to one of pozzelana beaten up in the ſame manner, and which if uſed with common lime, will fully anſwer for the faces of walls either ſtone or brick that are expoſed to water, either continually or ſubject to be wet and dry, in which laſt caſe the pozzelana greatly exceeds the terras, as *alſo in its lying quiet in the joints as the trowel has left them, without growing* as terras does.

As a piece of œconomy, I have found that if the mortar laſt mentioned is beaten up with a quantity of good ſharp ſand, it no ways impairs its durability, and increaſes the quantity. The quantity of ſand to be added depends upon the quality of the lime, and is thus determined: if to the pozzelana conſidered as mortar, you add as much real ſand as will make out the whole quantity, ſuch as an experienced workman would allow to his lime to make good common mortar, this will ſhew the quantity to be added, that is, may be originally beaten up together; thus, if the lime is of ſuch quality as to take two meaſures of ſand to one of lime, then one meaſure of pozzelana and three meaſures of ſand will ſatisfy two meaſures of lime.

The compoſitions above mentioned are ſeldom uſed further than for 6 inches within the face of the ſtone, or at moſt, for ſetting the ſtones and the bricks forming the face of the work, while the backing is wholly done with common mortar, and which under water never comes to the hardneſs and conſiſtence of ſtone, or forms that bond of union which would ariſe from a ſtony hardneſs; I have therefore found it preferable, where poz-

pozzelana can be had in plenty, to allow one bushel of pozzelana to eight bushels of the lime composing the mortar for backing.

The first composition will assuredly acquire the hardness of stone under water, and in 12 months will be as hard as Portland.

The hardening of the second and third depends greatly upon the quality of the lime, as also that of the fourth, yet there is scarcely any lime with which the materials well beaten up, in the proportion specified, will not acquire a very competent degree of hardness under water.

J. SMEATON.

Austhorpe,
23d *September* 1775.

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Strahan and Preſton,
Printers-Street, London.